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ABSTRACT

Papers from the proceedings of the 2000 Annual Meeting of the Association for the Education of Teachers in Science (AETS) include: (1) "A Quantitative Examination of Teacher Self Efficacy and Knowledge of the Anture of Science" (Chun, Sajin and Oliver, J. Steve); (2) "Investigating Preservice Elementary Teachers' Self-Efficacy Relative to Self Image as a Science Teacher" (Finson, Kevin D.); (3) "Development of a Self-Efficacy Beliefs about Equitable Science Teaching and Learning Instrument for Prospective Elementary Teachers" (Ritter, Jennifer M. and Rubba, Peter A.); (4) "Math Connections: Science and Engineering Applications in an Elementary Classroom" (Kelso, Robyn and Akerson, Valarie L.); (5) "Service Learning at Inventure Place: A Creative Model" (Broadway, Francis, S. and Clark-Thomas, Beth A.); (6) "Preparing Teachers as Reformers" (Trumbull, Deborah J.); (7) "A Theoretical Framework for Examining Peer Collaboration in Preservice Teacher Education" (Anderson, Christopher); (8) "Professional Development: What is Working in the State of Nevada" (Crowther, David T. and Cannon, John R.); (9) "Young Children's Interpretations of Aerial Views as it Relates to Their Ability to Understand the Earth as Spherical" (Hawkins, Barbara); (10) "Gleanings from Identical Twins Studying Science" (Mascazine, John R.); (11) "A Collaborative Effort between Education and Science Faculty to Improve the Education of Prospective Public School Teachers" (De Caprariis, Pascal; Barman, Charles R.; and Magee, Paula A.); (12) "How Middle Childhood In-service Teachers View the "Scientific Method"" (Weinburgh, Molly); (13) "Intracampus and Intercampus Collaborations: Lessons Learned" (Henriques, Laura and Hawkins, Barbara); (14) "M.A.T. Interns' Views of Scientists" (Carnes, G. Nathan); (15) "The Culture of Traditional Preservice Elementary Science Methods Students Compared to the Culture of Science: A Dilemma for Teacher Educators" (Spector, Barbara S. and Strong, Paschal N.); (16) "The National Science Teaching Standards as the Basis for Portfolio Assessment" (Moseley, Christine); (17) "Using Web-Based Portfolios to Support Elementary Science Teacher Learning" (Zembal-Saul, Carla; Boardman, Leigh Ann; and Dana, Tom); (18) "Assessing Elementary Science Teaching in a Performance Setting" (Guy, Mark D. and Wilcox, Jackie); (19) "Improving Preservice Elementary Teachers' Conceptions of the Nature of Science Using a Conceptual Change Teaching Approach" (Akerson, Valarie L. and Abd-El-Khalick, Fouad); (20) "Improving Elementary Teachers' Conceptions of Nature of Science in the Context of a Science Content Course" (Abd-El-Khalick, Fouad); (21) "Project

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T.E.A.M.S. (Teacher Education at Akron for Mathematics and Science)" (Owens, Katharine D.; Broadway, Francis S.; and Griffin, C. Frank); (22) "Science Teacher Beliefs: Toward an Understanding of State Science Exams and Their Influence on Teacher Beliefs" (Veronesi, Peter and Van Voorst, Conrad); (23) "A Collaboration between Scientists and a Science Educator Developing Web-Based Curricular Activities" (Bodzin, Alec M.; Wilson, Ellen; and Hug, Barbara); (24) "Inter-Institutional Efforts to Develop a Web Based STS Course" (Spector, Barbara S.; Burkett, Ruth; Barnes, Marianne; and Johnson, Judith); (25) "What We Know about Our Future Math and Science Teachers" (Morrell, Patricia D.); (26) "Consideration of an Alternative Dissertation Format" (Gerber, Brian L.); (27) "The Nature of Science in Decision-Making: Lead Role, Supporting Character, or Out of the Picture?" (Bell, Randy L. and Lederman, Norman G.); (28) "Designing Video-Based Science Content Instruction for Elementary Teachers" (Abell, Sandra; Finkelstein, Nancy; Flick, Larry; Greenwood, Anita; and Wainwright, Camille); (29) "Science Education in an Urban Elementary School: Case Studies of Teacher Beliefs, Classroom Practices, and Staff Development" (King, Kenneth; Shumow, Lee; and Lietz, Stephanie); (30) "Shifting toward Inquiry Science Teaching: The Story of Secondary Science Teachers Working on Emergency Permits" (Moscovici, Hedy); (31) "Technology Advancing a Continuous Community of Learners (TACCOL)" Harry, Vicki D. and Carbone, R. Elaine); (32) "Globe Citizen Scientists with a Satellite Connection" (Bombaugh, Ruth); (33) "Enhancing Science Education Preservice and Inservice Teacher Professional Development Using Globe Environmental Science Curricula" (Ramey, Linda K. and Tomlin, James); (34) "Pre-service Secondary Science Teachers' Concerns Regarding Use of Calculator-Based Laboratory Scientific Probeware" (Wetzel, David R. and Varrella, Gary F.); (35) "Preservice Science Teachers and Internet Telecommunications Tools: Issues to Consider" (Bodzin, Alec M.); (36) "The 10th Anniversary of a Successful Elementary Science Teacher Preparation Program" (Lee, Cherin A.; Krapfl, Lisa; and Steffen, Angela); (37) "Electronic Concept Mapping as a Professional Development Focus for Health Sciences and Technology Academy (HSTA) Teacher-Participants" (Rye, James A.); (38) "Modeling Behaviors for Young Scientists: Video Technology as a Tool for Modeling Inquiry Skills" (King, Kenneth P. and Thompson, Thomas E.); (39) "Connecting Science, Social Studies, and Language Arts: An Interdisciplinary Approach" (Akins, Amy and Akerson, Valarie); (40) "Distance Education for Newbies" (Lennex, Lesia C.); and (41) "Preparing to Teach: Building an Epistemology Based on Practice and Theory" (Varrella, Gary F. and Veronesi, Peter). (YDS/NB)

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Preface

These proceedings of the 2000 Annual International Conference of the Association for the Education of Teachers in Science, held in Akron, Ohio, January 6-9, 2000, are the fifth in the set of proceedings of AETS annual conferences. We are pleased to have had the opportunity to edit them. Over 40 papers and summaries of presentations from the conference are included here, along with a copy of the conference program. The papers and presentation summaries are ordered by the corresponding conference session designation and by the first author's last name if it did not appear in the printed conference program.

Each paper and presentation summary submitted for inclusion in the proceedings was reviewed by one of the four editors. Because these proceedings are to serve as a record of the 2000 AETS annual meeting, the papers and presentation summaries were not heavily edited and were not refereed. Those papers and presentation summaries that were revised and returned by a designated date were included.

These proceedings are disseminated via the ERIC Clearinghouse for Science, Mathematics and Environmental Education in microfiche form (with hard copy available through ERIC) and on the AETS World Wide Web Site at URL http://www.aets.unr.edu/. Given ERIC documents and web materials are not copyrighted, papers and presentation summaries included in these proceedings may be submitted for publications in journals such as the *Journal of Science Teacher Education* and *Science Education.* For information on how to secure a microfiche or hard copy of these proceedings through ERIC, see your campus or local library, WWW URL http://edrs.com/, or phone 800-433-ERIC. Also, the papers and presentation summaries included in these proceedings may be downloaded directly from the AETS WWW site as a RTF (Rich Text Format) file.

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Acknowledgment

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2000 AETS Conference Program

Association for the Education of Teachers in Science, 2000 Annual International Conference, January 6-9, 2000: Akron, OH

2000 AETS Conference Papers and Presentation Summaries

Dear AETS Colleagues:

Welcome to Akron and to the 2000 AETS International Convention, your first professional meeting of the new millennium.

Why Akron? Because Akron is America's center of creativity. In 1995 Inventure Place: Home of the National Inventors Hall of Fame opened its doors. Why Akron? Because Ohio is the mother of invention, having produced Thomas Edison, the Wright Brothers, and others; and because northeast Ohio has been a national leader over the years in the number of patents issued.

The convention program has been designed to highlight creativity, invention and problem solving. You're in for a treat at the Friday night reception which will introduce you to the National Inventors Hall of Fame at Inventure Place. Be a kid. Play. Enjoy. Inventure Place defies definition. It's neither a science center nor a children's museum, but shares many features in common with this mushrooming part of the informal science education movement. Rather, Inventure Place celebrates creativity, the creativity of those who have become honored inductees of the National Inventors Hall of Fame and the nascent creativity of children from two to one hundred and two.

Should science educators be concerned with creativity? The answer is obvious. We want to share this unique addition to the informal science education community with all science educators. Learn. Have fun. And take back ideas that can enrich science in your area.

An endeavor such as this convention requires the efforts of many people. Please join us in thanking all of our committee members. Many people have devoted uncounted hours in a labor of love. We, along with you, appreciate very much their hard work.

Also, we very much appreciate our sponsors and exhibitors. When you visit with them, please tell them how important their support is for science education.

Have a great meeting. We're glad you're here.

Walter S. Smith and Charlene M. Czerniak
Convention Co-Chairpersons

BSCS Advertisement

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General Conference Schedule

2000 AETS Annual Meeting -- January 6–9, 2000
Radisson City Center Hotel, Akron, Ohio

Wednesday, January 5, 2000

Evening	AETS Board Meeting

Thursday, January 6, 2000

8:00 – Noon	AETS Board Meeting
9:00 – Noon	Preconference Workshops A1 to A4
9:00 – 4:00	Preconference Workshops A5 & A6
1:00 – 2:00	Session T1.1 to T1.6
2:20 – 3:20	Session T2.1 to T2.6
3:40 – 4:40	Session T3.1 to T3.6
5:00 – 6:00	General Session in Salon A: Nicholas D. Frankovits (Executive Director, *Partnership for America's Future)* and Jeff Wilhite (Vice President and Chief Operating Officer, *National Inventors Hall of Fame)* and Students Engaged in Invention – "Interactive Re-Engagement: From the Front Porch to the Patio"
6:00 - 8:00	Reception and Poster Session in City View North

Friday, January 7, 2000

6:15 - 8:00	Continental Breakfast
6:30 – 8:00	AETS Committee Meetings
8:00 – 9:00	Session F1.1 to F1.8
9:20 – 10:20	Session F2.1 to F2.8
10:40 – 11:40	Session F3.1 to F3.8
Noon – 2:00	Luncheon in Salon A. Speaker – Alan McCormack "Developing Inventiveness and a Sense of Wonder in Science Teachers"
2:20 – 3:20	Session F4.1 to F4.8
3:40 – 4:40	Session F5.1 to F5.8
5:30 – 8:00	Reception at Inventure Place

Saturday, January 8, 2000

6:15 - 8:00	Continental Breakfast
6:30 – 8:00	AETS Committee Meetings
8:00 – 9:00	Session S1.1 to S1.8
9:20 – 10:20	Session S2.1 to S2.8
10:40 – 11:40	Session S3.1 to S3.8
Noon – 2:00	Luncheon: Awards Banquet and Business Meeting in Salon A
2:20 – 3:20	Session S4.1 to S4.8
3:40 – 4:40	Session S5.1 to S5.7
6:30	Women in Science Education Dinner

Sunday, January 9, 2000

7:00 - 9:00	Continental Breakfast
7:30 – 9:00	AETS Executive Board
9:00 – 11:00	General Session: Dialogue Between the Glenn Commission and the AETS Membership

Pre-Conference Workshops
Thursday, January 6^{th}, 2000

Half Day *Thursday, Session A1—Workshop*

$10

Assisting Interns Through Networking and Field Support

Thomas R. Koballa, University of Georgia; Bill Baird, Auburn University

Half Day *Thursday, Session A2—Workshop*

$30

Using Children's Stories, Storytelling and Other Language Activities to Teach Elementary School Science

Jim Shymansky, University of Missouri- St. Louis; Larry Yore, University of Victoria; Jo Anne Ollerenshaw, University of Nebraska; Brian Hand, Iowa State University

Half Day *Thursday, Session A3—Workshop*

$15

Making and Sharing Rubrics for Use in Science Teacher Preparation Programs

Robert James, Texas A & M University; Caroline Beller, University of Arkansas; Warren DiBiase, University of North Carolina, Charlotte; Joneen Hueni, Bellville High School; Patti Nason, Stephen F Austin State University; Kathryn Powell, University of New Mexico; Julie Luft, University of Arizona

Half Day *Thursday, Session A4—Workshop*

$10

Integrating Formal and Informal Science Education: Models of Collaboration

Judith Sweeney, Museum of Natural History, Providence, RI; George Davis, Moorhead State University

All Day *Thursday, Session A5—Workshop* *SUMMIT*

$30 (includes lunch)

INTASC: How to Read a Beginning Science Teachers Portfolio- Interstate New Teacher Assessment and Support Consortium

Angelo Collins, Vanderbilt University; Lisa Stooksberry, Vanderbilt University

All Day *Thursday, Session A6—Workshop*

$12

Developing Collaborative Research Agendas

Robin Lee Harris Freedman, Buffalo State University; Bambi Bailey, Texas A & M International University

1:00 - 2:00 p.m. *Thursday, Session 1.1—Panel* City View North

Teachers Get to Be Scientists!

Penny J. Gilmer, Florida State University; Jane B. McDonald and Sherri Hood, James S. Rickards High School

The steps will be described for a program uniting practicing and prospective high school science teachers with scientists for a summer collaborative science research experience.

1:00 - 2:00 p.m. *Thursday, Session 1.2—Panel* Salon C

Classroom Applications of Virtual Field Trips for Use in Science Classrooms (K-16)

Janet Woerner, California State University, San Bernardino; J. Preston Prather, University of Tennessee at Martin; Robert L. Hartshorn, University of Tennessee at Martin

Virtual Field Trips, providing field experiences through interactive computer technologies, create new roles for teachers and present opportunities for and barriers to effective instruction.

1:00 - 2:00 p.m. *Thursday, Session 1.3—Papers* City View South

Mathematics, Science, and Technology (MSAT) Education: An Integrated Preservice Teacher Certification Program

Donna Berlin, Ohio State University; Arthur L. White, Ohio State University

This session reports on the design, implementation, and evaluation of a grade 7-12 post baccalaureate preservice certification program that integrates mathematics, science, and technology education.

Restructuring Elementary Teacher Preparation Programs To Integrate Content And Pedagogy

Kathy Norman, California State University San Marcos

Presenter will describe an innovative elementary teacher preparation program that integrates content specific pedagogy and field experiences with content courses throughout three years of study.

Energy Education as a Theme for a Content/Methods Course

William Baird, Auburn University; Ralph Zee, Auburn University

Describes the use of energy as a theme in a hybrid methods/content course for physical science teachers, with examples of class demonstrations, problems, and group projects from this course

1:00 - 2:00 p.m. *Thursday, Session 1.4—Papers* City View East

Investigating Preservice Elementary Teachers' Self-Efficacy Relative to Self Image as a Science Teacher

Kevin Finson, Western Illinois University

This presentation will examine possible relationships between preservice teachers' self image as revealed through four DASTT-C variables and self efficacy as measured using the STEBI-B.

A Quantitative Examination of Teacher Self Efficacy and Knowledge of the Nature of Science

Sajin Chun, University of Georgia; J. Steve Oliver, University of Georgia

Examination of self efficacy, knowledge of the nature of science, and teaching concerns of inservice middle school science teachers participating in a 3 year workshop.

The Development and Validation of the Self-Efficacy Beliefs about Equitable Science Teaching and Learning Instrument for Prospective Elementary Teachers

Jennifer Ritter, Millersville University; Peter A. Rubba, Penn State University

The purpose of this study was to develop, validate and establish the reliability of an instrument to assess the self-efficacy beliefs of prospective elementary teacher regards to science teaching and learning for diverse learners.

1:00 - 2:00 p.m. *Thursday, Session 1.5—Interactive Session* Summit

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The NSTA/NCATE Performance Standard for Content: An Interactive Session

Steven Gilbert, Indiana University Southeast

An interactive session in which teacher educators are invited to discuss the most recent, performance-based NSTA/NCATE content standard for teacher preparation.

1:00 - 2:00 p.m. *Thursday, Session 1.6—Interactive Session* Airship

---

The Development of Performance Standards for Accreditation and Certification

Robert Fisher, Illinois State University

The session will describe how Illinois has developed standards for the initial and continuing preparation of teachers of science.

NC-AETS Dinner Meeting and Social Gathering
Bring Friends! Recruit a potential NCAETS Member!
Thursday, January 6, 2000
Meet in the Hotel Lobby at 6:30 p.m. Look for the signs!

Concurrent Sessions, Thursday 2:20 – 3:20 p.m.

2:20 - 3:20 p.m. p.m. *Thursday, Session 2.1—Panel* City View North

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The Committee on Inclusive Science Education Presents Dr. Mary Monroe Atwater

S. Maxwell Hines, Hofstra University; Mary Atwater, University of Georgia; Barbara Crawford, Pennsylvania State University; M. Virginia Epps, University of Wisconsin-Whitewater; Juanita Jo Matkins, University of Virginia; Marcia Fetters, University of Toledo

An interactive symposium on MCSE with Dr. Mary Monroe Atwater. She and committee members will examine the history and future of MCSE. Audience participation encouraged

2:20 - 3:20 p.m. *Thursday, Session 2.2—Papers* Salon C

Validating the Draw-A-Science-Teacher-Test Checklist (DASTT-C)

Julie Thomas, Texas Tech University; Jon E. Pedersen, East Carolina University; Kevin D. Finson, Western Illinois University

Test creators will share the process of validating the Draw-A-Science-Teacher-Test-Checklist (DASTT-C), a measure of stereotypic images of an elementary science teacher at work.

Math Connections: Science and Engineering Applications in an Elementary Classroom

Robyn Kelso, Richland (WA) High School; Valarie Akerson, Washington State University

This session describes research results of a preservice elementary teachers' processes for using science and engineering to help her students make real world math connections.

2:20 - 3:20 p.m. *Thursday, Session 2.3—Papers* City View South

Creating Positive Learning Environments

Burnette Hamil, Mississippi State University

Creativity, as an important aspect of the learning environment, can lead to positive results in relation to teaching and learning in the science classroom.

Making Elementary Science Methods Real: In To The Classroom And Out To The World

Bruce Johnson, Gustavus Adolphus College

Preservice elementary science methods students plan and implement an ecosystems unit with local 3rd graders, both in the classroom and in the outdoors.

Classroom Management and Discipline Techniques Utilized by Exemplary Science Teachers

Scott Watson, East Carolina University

The purpose of this study was to identify science teachers with exemplary classroom and management skills, and to determine specific methods and techniques they utilize.

2:20 - 3:20 p.m. *Thursday, Session 2.4—Papers* City View East

The Caring Culture of an Urban Middle School

Maria Ferreira, Wayne State University

The study examined several dimensions of school functioning to determine how they contributed to or hindered the development of a caring culture in an urban middle school.

Learning to Teach by Coteaching in Communities of Prospective and Practicing Science Teachers

Gale Seiler, University of Pennsylvania; Kenneth Tobin, University of Pennsylvania

An urban teacher education program in science was redesigned around a nucleus of coparticipation. The program is described and its implications explored.

Preparing to Teach - Building An Epistemology Based on Practice and Theory

Gary Varrella, George Mason University; Peter D. Veronesi, State University of New York, College at Brockport

A study of preservice epistemological development using a strategy called the science teaching rationale. Evidence of success, instrument validity and reliability, and recommended methods to be included.

2:20 - 3:20 p.m.	*Thursday, Session 2.6—Demonstrations*	Airship

Service Learning at Inventure Place: A Creative Model

Francis Broadway, University of Akron; Beth Clark-Thomas, Malone College

Service Learning at Inventure Place was designed to challenge preservice science teachers' concept of science teaching and learning. Program design and artifacts will be shared.

Field Experiences: Enhancing the Field Trip

John Mascazine, Ohio State University; Andrea Karch Balas, Ohio State University

This presentation will explain how to improve and maximize the use of field sites. The field experience includes four components: pre-visit preparation, the experience, classroom follow-up, and a re-visit.

Concurrent Sessions, Thursday 3:40 – 4:40 p.m.

3:40 - 4:40 p.m.	*Thursday, Session 3.1—Interactive Session*	City View North

Do Student's Beliefs Change Over a Semester of Constructivist Teaching?

Robin Freedman, Buffalo State College; Patricia Gathman Nason, Department of Elementary Education; Gary F. Varrella, George Mason University

Elementary and secondary methods student's beliefs are compared, using a student belief statement and the BALE evaluation instrument. Students attend two different schools.

3:40 - 4:40 p.m.	*Thursday, Session 3.2—Panel*	Salon C

Integrating Technology into Science Education

Martha Schriver, Georgia Southern University; J. M. Shireen Desouza, Ball State University; Richard Audet, Roger Williams University; Gerry Saunders, University of Northern Colorado

This panel will discuss how and what types of technology are presently being integrated into the science teacher preparation programs at various universities.

3:40 - 4:40 p.m. *Thursday, Session 3.3—Papers* City View South

Assessing Pre-service Elementary Teacher's Understanding about Osmosis Through an Inquiry Activity

John T. Norman, Wayne State University

Pre-service elementary teachers were given a problem solving assignment that required some understanding of osmosis to successfully solve. Many teacher misconceptions were revealed and categorized.

A Problem Solving Approach to the Laboratory for an Undergraduate Course in Introductory Chemistry

James Ellis, University of Kansas; Joseph A. Heppert and Janet Bond Robinson, University of Kansas

Describes a college laboratory course that is problem-centered, inquiry-oriented and that uses cooperative learning and computer-based technology to promote teaching and learning.

Reconceptualizing a General Chemistry Curriculum Using a Standards-based Approach to Instruction

Warren DiBiase, University of No. Carolina at Charlotte; Eugene Wagner, University of No. Carolina at Charlotte

Session will provide an overview of Operation CHEM 1251. The project involves making major revisions to the general chemistry program at UNC-Charlotte by developing and implementing concept modules based on a Standards-based approach to instruction.

3:40 - 4:40 p.m. *Thursday, Session 3.4—Papers* City View East

The Interdisciplinary Systemic Reform of Science Instruction in Grades 6-10 in West Virginia

Eric Pyle, West Virginia University; Warren J. DiBiase, University of North Carolina at Charlotte; Phyllis Barnhart, West Virginia Department of Education; Patricia Obenauf, West Virginia University

This paper describes how Project CATS (Coordinated and Thematic Science), prepares teachers in grades 6-10 with the expertise to organize science instruction in an interdisciplinary thematic manner.

Science Teacher Education and Reform- An Instrument to Measure Opportunities to Learn (OTL)

William Boone, Indiana University-Bloomington; Kathryn Scantlebury, University of Delaware; Jane Butler Kahle, Miami University

This paper describes the development of an instrument that provides student measures on three dimensions of opportunities to learn. Techniques of utilizing the instrument for science teacher education will be presented.

Can We Help our Preservice Teachers Become Agents of Reform?

Deborah Trumbull, Cornell University

Reform documents call for changes in science teacher education in order to allow new teachers to be agents of reform. This paper uses data from a longitudinal study to argue that we can do this, but need to change our emphases.

3:40 - 4:40 p.m. *Thursday, Session 3.5--Demonstrations* Summit

Teaching Highly At-Risk Students Math and Science: A Sea Island Perspective

Meta Van Sickle, University of Charleston; mutindi ndunda, University of Charleston

Two professors worked with one high school class for 3 years. Data and teaching techniques that helped students pass high school exit exams will be presented.

What Works When You Mess Around with Science: Manipulatives for Second Language Learners

Isabel Quita, San Francisco State University

Hands-on manipulative activities for second language learners in an elementary classroom will be explored. Participants will be engaged in cooperative group activities.

3:40 - 4:40 p.m. *Thursday, Session 3.6—Interactive Session* Airship

Teach Them the Way You Would Like Them to Teach

Robert Ketcham, University of Delaware; Steven Fifield, University of Delaware

A college biology lab course has been reformed to put student participation at the center of the learning process. Training the lab instructors in the use of Pair-Share Discussions is a major part of making the reform successful.

Opportunity for Graduate Students to Ask, "What Happens Next?"

Join relatively new faculty from various universities for lunch as an opportunity to inquire about the transition from graduate school to a faculty position. You will have the chance to discuss balancing the demands of teaching, research, and service, all while attempting to establish oneself in an institution and a community. Limited seating at special tables during the business meeting luncheon will be reserved for graduate students that sign up at the registration table prior to the luncheon. So if you want to learn from those that are currently living it, take advantage of this invitation and join us.

5:00 – 6:00 p.m *General Session* Salon A

Interactive Re-engagement: From the Front Porch to the Patio

Nicholas D. Frankovits, Executive Director
Partnership for America's Future
Jeff Wilhite, Vice President and Chief Operating Officer
National Inventors Hall of Fame
and Students Engaged in Invention.

Poster Session and Reception

6:00–8:00 p.m. *Thursday Session 6.1 —Posters* City View North

Electronic Publishing in the 21st Century: Its Impact on Scholarly Writing

John Cannon, University of Nevada, Reno; David T. Crowther, University of Nevada, Reno

The ever changing state of electronic publication, scholarly writing and promotion and tenure will be discussed. A demonstration of writing for electronic publication will follow.

Teachers' Preparation to Implement the Texas Science Curriculum

Gil Naizer, Texas A&M Commerce; Haydn Fox, Texas A&M Commerce

Presents results from a survey and process skills test determining NE Texas teachers level of preparedness to implement the newly implemented state science curriculum.

Preparing Pre- and Inservice Educators to Use Inquiry-Based Science in Outdoor Settings

Alan Sowards, Stephen F. Austin University; Gilbert Naizer, Texas A&M University–Commerce; Cheryl Tate, Stephen F. Austin University

A visual display of pre- and in-service educators participating in a professional development program that integrates hands-on elementary curriculum and instruction utilizing outdoor settings.

Peer Collaboration in a Preservice Elementary Teacher Training Program

Christopher Andersen, Ohio State University

In successful peer coaching, partners appear to work together to support each others' developing metastrategic control of new teaching strategies.

Lessons Learned: A Closer Look at a Museum Outreach Program

James Kisiel, Natural History Museum of Los Angeles County & USC

Two unique trailer-truck-based museum outreach programs were examined to study the influence of these extremely popular programs on teacher practice and implications for the development a third program.

Embracing Diversity in Science Education: The Facilitation of Understanding in Inclusive Science Education

Hsing Chi Wang, Michigan State University; Anne M. Cox-Petersen, California State University Fullerton; Patricia Thompson, University of Southern California; LaNelle Harvey, Los Angeles Unified School District; Leland S. Cogan, Richard T. Houang, and William H. Schmidt, Michigan State University; Joanne K. Olson, Iowa State University

In collaboration with the Inclusive Science Education Committee of AETS, six exhibits based on inclusive science education will facilitate understanding among science education community.

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CESSE Advertisement

Friday 6:30–8:00 a.m.

Early Morning Committee Work

6:30 - 8:00 a.m. *AETS Committee Meetings* Rooms TBA

Regional Directors-------------------------------- ______________

Elections -- ______________

Long Range Planning--------------------------- ______________

Financial Advisory ------------------------------ ______________

Membership--------------------------------------- ______________

Inclusion --- ______________

Concurrent Sessions, Friday 8:00–9:00 a.m.

8:00 - 9:00 a.m. *Friday Session 1.1—Panel* City View North

Integrating the Manned Flight to Mars into Science Teacher Preparation

Robert James, Texas A&M University; Jon Borowiec, Texas A&M University; Don Christenberry, Craigmont High School

This presentation will address developing and integrating a manned mission to Mars unit into preservice/inservice science teacher preparation programs.

8:00 - 9:00 a.m. *Friday Session 1.3—Papers* City View South

Children's Interpretations of Aerial Views as it Relates to their Ability to Understand the Earth as Spherical

Barbara Hawkins, California State University, Northridge

This paper presents study results examining children's interpretations of aerial views, for use of earth observing satellite data to shape notions of the earth as spherical.

Gleanings from Identical Twins Studying Science

John Mascazine, Ohio State University

This presentation will focus on qualitative data collected using case study and in-depth interviewing techniques with four pairs of adult identical twins who were preparing for science related professions.

Giving Voice to Elementary Students in Science Education Research: First Graders as Teacher-Educators

Judith McGonigal, Curtin University of Technology

Nineteen first graders co-researched science inquiry implementation in their classroom. This paper documents how these students, as teacher-educators, shared their insights with teachers and educational researchers.

8:00 - 9:00 a.m. *Friday Session 1.4—Papers* City View East

A Collaborative Effort Between Education and Science Faculty

Charles Barman, Indiana University Purdue University Indianapolis; Pascal de Capariis, IUPUI, Paula Magee, IUPUI

This presentation will discuss how a geology course was organized to use small group activities in a large lecture class. Evaluation data related to students' science understandings perceptions of the class will be presented.

Scientific Literacy as a Goal OF College Science from the Perspective and Teaching of Two Graduate Students

Sufen Chen, Indiana University

This qualitative research revealed conflicting interpretations of scientific literacy in the perspectives and teachings of two physics graduate students at a research university.

How Middle Childhood Inservice Teachers View the Scientific Method

Molly Weinburgh, Georgia State University

The purposes of this research was to explore ways in which the concept of "scientific method" changes as teachers engage in a reflective activity on the nature of the scientific method.

8:00 - 9:00 a.m. *Friday Session 1.5—Papers* Summit

Inservice Duration Impact on Inquiry Science Practice Adoption

Lucy Slinger, UW-La Crosse; Peter M. Mecca, Department of Defense

The immediate effect of several different models of inservice workshops designed to promote inquiry science teaching practice adoption by middle and high school teachers will be presented.

A Formative Evaluation of a Preservice Teacher Education Practicum Course: Implications for Preservice Teacher Training

Greer Richardson, Temple University; Penny Hammrich, Temple University

The formative evaluation sought to monitor the extent to which the Education 231 Integrated Mathematics/Science Practicum course was implemented and which goals achieved.

How are our Graduates Teaching? Looking at the Learning Environments in our Graduates' Classrooms

Bruce Johnson, Gustavus Adolphus College

The Classroom Learning Environment Survey (CLES) was completed by preservice students and by recent graduates of Minnesota teacher education programs and by their students.

8:00 - 9:00 a.m. *Friday Session 1.6—Papers* Airship

Collaborative Design, Implementation and Evaluation of a Standards-Based Physics Course for Preservice Elementary Teachers

Ronald Atwood, University of Kentucky; John E. Christopher, University of Kentucky

An overview of rationale, procedures, and results of a collaborative project to design, implement and evaluate a standards-based physics course for preservice elementary teachers.

Science, Math and Teaching: A Unique Collaboration

William Kubinec, College of Charleston; Meta Van Sickle, College of Charleston

Educators and content specialists have forged an unusual master of education in science and mathematics programs. Content courses must employ several best practice pedagogies.

Intracampus and Intercampus Collaboration: Lessons Learned

Laura Henriques, California State University, Long Beach; Barbara Hawkins, California State University, Northridge

Project ALERT partners California State University and NASA faculty to improve science instruction for prospective teachers. Lessons learned for scientist/educator collaboration will be shared.

8:00 - 9:00 a.m. *Friday Session 1.7—Interactive Session* Ohio

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Professional Development: What is Working in the State of Nevada

David Crowther, University of Nevada, Reno; John R. Cannon, University of Nevada–Reno

This presentation will share the qualitative and quantitative findings of the Nevada Operation Chemistry program and the structure of the "teacher training teacher" model of professional development to create teacher change in the teaching of science.

8:00 - 9:00 a.m. *Friday Session 1.8—Interactive Session* Inventors

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Facilitating Inquiry Science Teaching Across a Ten University System

Bambi Bailey, Texas A&M International University; Kit Price, College of Science and Technology

Presenters will report current results of and seek feedback about some of the issues related to facilitating inquiry teaching at the college level.

2000 AETS Annual Conference Proceedings

Papers and summaries of presentations made at the 2000 AETS Annual Conference can be submitted for inclusion in the 2000 AETS Conference Proceedings. The Proceedings again will be published as an ERIC document through the ERIC Clearinghouse for Science, Mathematics and Environmental Education, with microfiche and hard copies available through ERIC. The 2000 Proceedings also will be available on the AETS World Wide Web Site (http://www.aets.unr.edu/), as are the 1996, 1997 1998, and 1999 Proceedings. Pete Rubba, Jim Rye, Pat Keig and Warren DiBiase will edit the 2000 Proceedings.

Guidelines for the preparation and submission of papers and presentation summaries for the 2000 Proceedings are available on the AETS World Wide Web Site (http://www.aets.unr.edu/). These guidelines differ in a number of respects from those for past proceedings. For example, all submissions are to be by mail within 30 days following the conference. AETS members are encouraged to review the new guidelines carefully. Please contact Pete Rubba with any questions.

Dr. Peter (Pete) A. Rubba
140 Chambers Building, Penn State University
University Park, PA 16802
Phone: 814-865-1500 FAX: 814-863-7602 E-Mail: par4@psu.edu

9:20 - 10:20 a.m. *Friday Session 2.1—Panel* City View North

Rationale Papers in Methods Courses Part II

Robin Freedman, Buffalo State College; John E. Penick, North Carolina State University; Ron Bonnstetter, University of Nebraska; Pradeep M. Dass, Northeastern Illinois University; Sandy Enger, University of Alabama in Huntsville; John W. Tillotson, Syracuse University; Gary F. Varrella, George Mason University; Peter Veronesi, SUNY Brockport; Jeffrey Weld, Oklahoma State University

A panel discussion on the use of rationale papers by pre-service teachers is discussed by faculty who use them.

9:20 - 10:20 a.m. *Friday Session 2.2—Papers* Salon C

Connecting Science, Social Studies, and Language Arts: An Interdisciplinary Approach

Amy Akins, Washington State University; Valarie L. Akerson, Washington State University

This session describes a research project undertaken by a preservice elementary teacher and her attempts to help students recognize the connections between three disciplines.

Inquiry Projects in Urban Middle Schools: Lessons Learned

Joe Krajcik, University of Michigan; Becky Schneider, Jon Singer, University of Michigan

This presentation describes results from an evaluation of two middle school inquiry projects enacted in an urban school district. A description of how the results were utilized to revise the curriculum is included.

Teachers' Wisdom Bringing Perspective to the Integration of Middle Level Mathematics and Science

Julie Saam, Indiana University

Results of a study of two teachers' attempt to integrate mathematics and science will be presented. The teachers' wise perspective of integration will be illuminated.

9:20 - 10:20 a.m. *Friday Session 2.3—Demonstrations* City View South

Promoting Inquiry and Standards-based Teaching With the New Edition of the BSCS Blue Version

Jon Greenberg, Biological Sciences Curriculum Study (BSCS)

The Eighth edition of BSCS Biology: A Molecular Approach, available this spring, stimulates critical thinking with updated science, more inquiry-based activities, and greater readability

A Multimedia Approach for Teaching Taxonomy and Systematics in High School Biology

David Hanych, Biological Sciences Curriculum Study (BSCS)

New instructional multimedia promotes inquiry-based learning of taxonomy and systematics, the nature and methods of science, and the implications of scientific discoveries.

9:20 - 10:20 a.m. *Friday Session 2.4—Papers* City View East

The Culture of Traditional Preservice Elementary Science Methods Students Compared to the Culture of Science: A Dilemma for Teacher Educators

Barbara Spector, University of South Florida; Paschal Strong, University of South Florida

Science culture compared to traditional elementary methods students' culture; related psychological factors, and implications for teacher educators derived from studying six methods classed are described.

M.A.T. Interns' Views of Scientists

Nathan Carnes, University of South Carolina

The presenter will share images that elementary education M.A.T. interns had of scientists. The audience may participate in a discussion about influencing interns' visual images.

The Roles of the Cooperating Teacher in Constraining Opportunities to Learn to Teach Science in an Urban Setting

Gale Seiler, University of Pennsylvania

The experiences of a student teacher placed in a difficult urban setting with an inexperienced cooperating teacher yield suggestions for urban teacher education programs.

9:20 - 10:20 a.m. *Friday Session 2.5—Papers* Summit

Translation of Teachers' Views to Students' Understandings of the Nature of Science: Examining a Reform Based College Science Course

Julie Gess-Newsome, University of Utah; Sherry A. Southerland, University of Utah; Adam Johnston, Weber State University

This study describes the relationship between teachers' conceptions of teaching, students, and nature of science as it impacts course planning, course implementation, and student conceptions.

Collaboration: The Driving Force of the Texas Regional Collaboratives for Excellence in Science Teaching

James P. Barufaldi, University of Texas at Austin

The paper answers the question, "What makes collaboration work in science teacher professional development programs"? A professional development model, the Texas Regional Collaboratives for Excellence in Science Teaching that reflects the essence of both reform and collaboration, will be described.

Nature of Science and Classroom Instruction: A Comparison of Two Preservice Teachers

Reneé S. Schwartz, Oregon State University; Norman G. Lederman, Oregon State University

This case study comparison examines conceptions of nature of science and instructional attempts of two preservice teachers during student teaching. Factors influencing their variable successes are discussed.

9:20 - 10:20 a.m. *Friday Session 2.6—Demonstrations* Airship

Using Web-Based Portfolios to Support Elementary Science Teacher Learning

Carla Zembal-Saul, Pennsylvania State University; Leigh Ann Boardman, Pennsylvania State University; Mary Severs, Chicago Museum of Science and Industry

The purpose of this demonstration is to illustrate how web-based portfolio development is being integrated into an elementary science methods course to support teacher learning.

The National Science Teaching Standards as the basis for Portfolio Assessment

Christine Moseley, Oklahoma State University

Portfolios centered around the six National Science Teaching Standards are used as a major form of elementary preservice teacher assessment.

9:20 - 10:20 a.m. *Friday Session 2.7—Interactive Session* Ohio

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Outside the Hotel: Continuing the Challenging Dialogue and Critical Discourse

Patricia Simmons, University of Missouri-St. Louis; John Penick, University of North Carolina; Andy Kemp, University of Louisville; Bob Cohen, East Stroudsburg University; Val Olness, Augustana College

This session continues the dialogue about how we can "make a difference" by developing a working agenda and action plan about essential science teacher education experiences.

Concurrent Sessions, Friday 10:40–11:40 a.m.

10:40 - 11:40 a.m. *Friday Session 3.1—Panel* City View North

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Nature of Science: Implications for Research, Assessment and Teacher Education

Ron Good, Louisiana State University; Norm Lederman, Oregon State; Bill McComas, UCLA; Julie Gess-Newsome, University of Utah; Catherine Cummins, Louisiana State University

This symposium will consider ways to use Benchmarks and Standards as guides for nature-of-science research, assessment, and teacher education.

10:40 - 11:40 a.m. *Friday Session 3.3—Papers* City View South

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Assessing Science Teaching in a Performance Setting

Mark Guy, University of North Dakota; Jackie Wilcox, University of Dubuque

Preservice elementary teachers enrolled in a science methods course participated in a performance assessment of inquiry-based science teaching with young children.

Science Classroom Cases as a Context for Research: Investigating Teachers' Responses to a Classroom Controversy

Deborah Tippins, University of Georgia; Tom Koballa, Ruth Leonard, Nam Hwa Kang, David Jackson, University of Georgia

We will present our efforts to engage teachers in reflective inquiry about a classroom controversy associated with Stephen Hawking's Video, A Brief History of Time.

Developing a Statewide Research Network to Conduct a Qualitative Study of Pre-Service and Early In-Service K-12 Science and Math Teachers

George Davis, Moorhead State University; Patricia Simpson, St. Cloud State University

Six institutions have conducted a qualitative research study of K-12 science and math teachers determining process and instruments to describe teacher effectiveness.

10:40 - 11:40 a.m. *Friday Session 3.4—Papers* City View East

Improving Preservice Elementary Teachers' Conceptions of the Nature of Science Using a Conceptual Change Teaching Approach

Valarie Akerson, Washington State University; Fouad Abd-El-Khalick, American University of Beirut

This session describes a research study that explored the results of using a conceptual change teaching approach in influencing changes in elementary teachers' views of the nature of science.

Creating School-Based Teacher Leaders

Charlene M. Czerniak, University of Toledo; Jodi Haney, Bowling Green State University

This session describes the process used in an NSF Local Systemic Change grant in an urban school district to create K-6 school-based science teacher leaders.

Influences on the Conceptual Change Process: Motivation, Prior Experiences with Science, and Classroom Activities

Joanne Olson, Iowa State University

This session will explore the role of motivation in conceptual change, including differences noted between students at high, moderate, and low levels of conceptual change.

10:40 - 11:40 a.m. *Friday Session 3.5—Interactive Session* Summit

How Do Women Faculty in Science Education Define and Celebrate Professional Excellence?

Barbara Spector, University of South Florida; Marianne Barnes, University of North Florida; Judith Johnson, University of Central Florida; Carole Briscoe, University of West Florida; Patricia Simmons, University of Missouri-St.. Louis; Patricia Simpson, St. Cloud State University; Cathy Yeotis, Wichita State University; Carolyn Butcher Dickman, Radford University; Meta Van Sickle, University of Charleston; Robin Freedman, Buffalo State College

At this women's networking meeting, we will share strategies for defining, sustaining, and celebrating women faculty's professional excellence in science education. Men are welcome.

10:40 - 11:40 a.m. *Friday Session 3.6—Papers* Airship

Learning to Teach Science as Praxis

Wolff-Michael Roth, University of Victoria; Ken Tobin, University of Pennsylvania

An examination of the theoretical underpinnings of science teacher education. Implications of teaching being regarded as knowledge in action are considered for science teacher educators.

Learning to Teach and Teaching to Learn

Josefina Arce, University of Puerto Rico; Jose R. Lopez, University of Puerto Rico

The effective use of Interactive Demonstrationsin the classroom and laboratories will be ,modeled as well as ways to assess conceptual understanding of the discussed concepts.

Using International Collaborations to Enrich and Reform the Science and Environmental Education Classroom

Fletcher Brown, University of Montana; Lisa Blank, University of Montana

This presentation describes and critiques a two year inservice environmental education teacher training program involving teachers from Hungary and the United States.

10:40 - 11:40 a.m. *Friday Session 3.7—Demonstrations* Ohio

A Collaborative Model to Infuse Technology into Elementary Science Methods Courses

Juanita Jo Matkins, University of Virginia; Elizabeth Klein, State University of New York - Cortland; Starlin Weaver, Salisbury State University

Three institutions in three different states instituted a collaboration using realtime team-teaching and purposeful student collaboration.

Project T.E.A.M.S. (Teacher Education at Akron for Mathematics and Science)

Katharine Owens, University of Akron; Francis S. Broadway, University of Akron; C. Frank Griffin, University of Akron

Project T.E.A.M.S. focuses on establishing a shared understanding of national standards, of inquiry methodologies, and of authentic assessment by all educators involved in teacher preparation

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10:40 - 11:40 a.m. *Friday Session 3.8—Interactive Session* Inventors

Developing a Community of Educators Teaching With and About the Environment: Understanding Science Stuff and Doing Something With It

Margaret Bogan, Jacksonville State University

EPA-funded Environmental Education Institute participants experienced teaching to learning styles, EE philosophy, science process/techniques, social science theory/civic behavior, PCK and indigenous spirituality which broadened understanding of how science works in relation to other disciplines.

Noon – 2:00 p.m *Luncheon* Salon A

Developing Inventiveness and a Sense of Wonder in Science Teachers

Alan J. McCormack
San Diego State University

Concurrent Sessions, Friday 2:20–3:20 a.m.

2:20 - 3:20 p.m. *Friday Session 4.1—Panel* City View North

Looking to the Future: Potential Changes in the Organizational Structure of AETS (1st of 2 sessions)

Julie Gess-Newsome, President, AETS; John Staver, Kansas State University; Larry Flick, Oregon State University; Bill Boone, Indiana University

AETS is a vital organization with its own national meeting and journal. Is our current organizational structure responsive to our current needs? This session will provide a forum to discuss proposed changes within AETS.

2:20 - 3:20 p.m. *Session Friday – 4.2—Paper & Demonstration* Salon C

Misrepresentation of the Moon

Kathy Trundle, University of Kentucky

This session focuses on the misrepresentation of the moon in children's literature and popular press, which unfortunately reinforces alternative conceptions about moon phases.

The Moon Investigation: A Discrepant Event for Future Elementary Science Teachers

Sandra Abell, Purdue University; Mariana Martini, Purdue University; Melissa George, Lafayette School Corporation

We will demonstrate strategies used in an elementary methods course moon study that lead to learner dissatisfaction with their theories of science teaching and learning.

2:20 - 3:20 p.m. *Friday Session 4.3—Interactive Session* City View South

Intelligent Television

Karen Leichtweis, The Annenberg/CPB Project

Check out THE ANNENBERG/CPB CHANNEL, a free satellite service carrying professional development programs for K-12 math and science educators, and a variety of popular PBS programs.

2:20 - 3:20 p.m. *Friday Session 4.4—Papers* City View East

Linking Preservice and Inservice Science Teacher Development: Action Research in the Rural School Environment

John W. Tillotson, Syracuse University

Action research provides a framework for teaming preservice interns and rural inservice science teachers in a project aimed at enhancing curriculum and integrating technology in five rural school districts.

Making Connections Between the Nature of Science and Scientific Inquiry: A Science Research Internship for Preservice Teachers

Reneé S. Schwartz, Oregon State University; Norman G. Lederman, Oregon State University; Barbara Crawford, Pennsylvania State University

This investigation assessed the effectiveness of an authentic science research experience, with reflection, on preservice teachers' conceptions of the nature of science and scientific inquiry.

Empowering Science Teachers as Researchers and Inquirers

Anne M. Cox-Petersen, California State University, Fullerton

Teacher research empowers teachers since the process involves active engagement to improve science instruction and learning. Science methods students conducted teacher research in their own classrooms.

2:20 - 3:20 p.m. *Friday Session 4.5—Papers* Summit

Science Teacher Beliefs: Toward An Understanding Of State Science Exams And Their Influence On Teacher Beliefs

Peter Veronesi, State University of New York, College at Brockport

This paper discusses results of a survey about science teachers' beliefs surrounding aspects of teaching within the Regents summative exam system of New York State.

Oklahoma Secondary Life Science Teacher's Attitudes Toward Teaching Evolution

Jeffrey Weld, Oklahoma State University; Jill C. McNew, Oklahoma State University

Findings from a study of all life science teachers in Oklahoma (the reputed Bible Belt Buckle) regarding their attitudes toward teaching evolution have lessons and implications for teacher preparation everywhere.

Explicit and Tacit Conceptions of Teaching and Learning Expressed by Students in a Model Science Teacher Education Program

Michael Clough, Iowa State University; Paul Numedahl, Colorado College; Craig A. Berg, University of Wisconsin-Milwaukee

Students, semester ending research-based framework papers and oral defenses were analyzed to determine their conceptions of learning and teaching after their second and third semester of science methods.

2:20 - 3:20 p.m. *Friday Session 4.6—Interactive Session* Airship

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"Doing Science" Online with the Science Junction

John C. Park, The SERVIT Group, North Carolina State University; Alec M. Bodzin; Lehigh University; Lisa Grable, North Carolina State University; April Cleveland, North Carolina State University

This presentation highlights the NC State Science Junction Web site that serves to promote the "doing" of science through Web-based student activities and resources for parents and science teachers.

2:20 - 3:20 p.m. *Friday Session 4.7—Demonstration (one hour)* Ohio

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Using the Project 2061 Textbook Evaluation Database

Jo Ellen Roseman, AAAS/Project 2061

Which textbooks will help students learn ideas that are key to national and state standards? Explore a new on-line database that provides access to critical reviews of more than two dozen science and mathematics textbooks for the middle grades.

2:20 - 3:20 p.m. *Friday Session 4.8—Interactive Session (120 min.)* Inventors

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Walking the Talk in Your Elementary Science Methods Course (part 1)

Catherine Yeotis, Wichita State University; Margaret Bolick, Wichita State University; Gary Varrella, George Mason University; Patti Nason, Stephen F. Austin State University; Caroline Beller, University of Arkansas; Barbara Spector, University of South Florida; M. Jenice Goldston, Kansas State University

Participants will (1) generate a self-study design, leading to reflective collaboration; (2) explore relevant steps in a journey to rethink instruction; and (3) take action toward the exemplary elementary science methods course vision.

3:40 - 4:40 p.m. *Friday Session 5.1—Panel* City View North

A Focus Group Responding to a National Survey of Science Education Doctoral Programs: What We "Aught" To Do For The Next Decade

Paul Jablon, University of Massachusetts Lowell; Norm Lederman, Oregon State University; Bill McComas, University of Southern California; Bob Yager, University of Iowa; Michael Padilla, University of Georgia

It is unclear how many science education doctoral graduates are needed and what their qualifications should be. A national survey was conducted to answer these questions. A panel will briefly respond to the report.

3:40 - 4:40 p.m. *Friday Session 5.2—Panel* Salon C

Comparisons of Best Practices in Science Teacher Education in the United States, Singapore, Malaysia, Japan, and Germany

Joseph Riley, University of Georgia; J. Preston Prather, University of Tennessee-Martin; Kathleen A. O'Sullivan, San Francisco State University; Kueh Chin Yap, Nanyang Technological University/National Institute of Education; Thomas R. Koballa, University of Georgia

Science teacher education in the United States, Japan, Germany, Singapore and Malaysia will be compared for insights into best practices in teacher induction, retention and performance.

3:40 - 4:40 p.m. *Friday Session 5.3—Papers* City View South

Teaching, Curriculum, and Assessment in Secondary School Biology in Kenya

Norman Thomson, University of Georgia

Standards in science education are set among the "wealthy industrialized" countries. Yet, worldwide, biology curricula rely on natural systems from marginalized countries. An analysis of the Kenyan biology syllabus (including indigenous knowledge), instruction, and national assessments are made.

Sisters in Science: Building Girls Interest and Achievement in Science and Mathematics

Penny Hammrich, Temple University; Greer Richardson, Temple University

Sisters in Science is a multifaceted educational intervention impacting the affective and academic lives of fourth and fifth grade girls in science and mathematics.

Global Science Literacy: A Modern Basis for Science Curriculum Restructure

Victor Mayer, Ohio State University

Conceptually organized curricula using the Earth System, the subject of all science disciplines, as the organizing concept provides curriculum content that is international in scope.

3:40 - 4:40 p.m. *Friday Session 5.4—Papers* City View East

Developing Visual/Spatial Thinking Through an Enrichment Program

Alan McCormack, San Diego State University; Cheryl L. Mason, San Diego State University

Presenters will explore research attempts to measure and promote visual/spatial thinking in school science programs, and highlight Project VISTA, a current VST-oriented science curriculum enrichment program.

The Unnatural Creative and Inventive Character of Science and its Implications For Teaching and Learning Science Content and Processes

Michael Clough, Iowa State University

The unnatural nature of much scientific thinking has significant implications for teaching and learning science, and preservice science teacher education.

Metaphors and Models: The Source of the Creative and Inventive Character of Science

Steven Gilbert, Indiana University Southeast

Will discuss the need for students and teachers to be able to analyze and understand the nature and use of models and metaphors in science.

3:40 - 4:40 p.m. *Friday Session 5.5—Demonstration* Summit

A Collaboration Between Scientists and a Science Educator Developing Web-based Curricular Activities

Alec Bodzin, The SERVIT Group, Lehigh University; Ellen Wilson, University of Utah; Barbara Hug, University of Utah

This session will illustrate how a science educator worked with a group of scientists to restructure an existing Web-based curricular science site to become more aligned with current reform initiatives in science education.

Integrated Studies in Middle School Science and English Education

Mark Volkmann, Purdue University; Margaret Finders, Purdue University

This session describes a collaboration between one science teacher educator and one English teacher educator to create integrated studies for preservice teachers at the middle level.

3:40 - 4:40 p.m. *Friday Session 5.6—Interactive Session* Airship

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Making a Smooth Transition from Graduate Student to Faculty

Lloyd Barrow, University of Missouri

This session will discuss potential higher education positions and typical responsibilities, interview strategies, and professional activities leading toward tenure.

3:40 - 4:40 p.m. *Friday Session 5.7—Interactive Session* Ohio

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Inter-Institutional Efforts to Develop A Web Based STS Course

Barbara Spector, University of South Florida; Marianne Barnes, University of North Florida; Judy Johnson, University of Central Florida

Presenters will describe and illicit reactions to the design and implementation of a web based Science/Technology/Society course for prospective and practicing teachers.

3:40 - 4:40 p.m. *Friday Session 5.8—Interactive Session (120 min.)* Inventors

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Walking the Talk in Your Elementary Science Methods Course (part 2)

Catherine Yeotis, Wichita State University; Margaret Bolick, Wichita State University; Gary Varrella, George Mason University; Patti Nason, Stephen F. Austin State University;

Caroline Beller, University of Arkansas; Barbara Spector, University of South Florida; M. Jenice Goldston, Kansas State University

Participants will (1) generate a self-study design, leading to reflective collaboration; (2) explore relevant steps in a journey to rethink instruction; and (3) take action toward the exemplary elementary science methods course vision.

5:30–8:00 p.m *Reception* Inventure Place

Inventure Place and National Inventors Hall of Fame

Award 1 — Outstanding Science Teacher Educator of the Year

1979	Rodger W. Bybee	BSCS
1980	Anton Lawson	Arizona State University
1983	William R. Capie	University of Georgia
1985	James Dudley Herron	Purdue University
1986	Charles R. Coble	East Carolina University
1987	John Penick	The University of Iowa
1988	James Barufaldi	University of Texas
1989	Lawrence F. Lowery	University of California
1990	William C. Kyle Jr.	Purdue University
1991	Barry Fraser	Curtin University of Technology
1993	Cheryl Mason	San Diego State University
1994	Patricia Simmons	University of Georgia
1995	J. Preston Prather	University of Virginia
1996	Sandra Abell	Purdue University
1997	Bonnie Shaprio	University of Calgary
1998	Patricia Simpson	St. Cloud State University

Award 2— Outstanding Science Teacher Educator of the Year

1997	John Penick	University of Iowas
1998	Hans Anderson	Indiana University
1999	Norman Lederman	Oregon State University

East Ohio Gas Advertisement

Award 3 – Honorary Emeritus Membership

N. Eldred Bingham
University of Florida

Clarence Boeck
University of Minnesota

R. Will Burnett
University of Illinois

Gerald Craig
Teachers College, Columbia University

Paul Dehart Hurd
Stanford University

Addison Lee
University of Texas

Ralph Lefler
Purdue University

Harold Tannenbaum
Hunter College

Edward Victor
Northwestern University

Milton O. Pella
University of Wisconsin

Fletcher Watson
Harvard University

Fred Fox
Oregon State University

Herbert Smith
Colorado State University

Alfred De Vito
Purdue University

Robert W. Howe
Ohio State University

Willard Jacobson
Teachers College, Columbia University

Steven Winter
Tufts University

Stanley Helgeson
Ohio State University

AETS Presidents

1932-34	S. Ralph Powers
1935-36	John C. Johnson
1936-38	W. L. Kikenberry
1938-40	E. Laurence Palmer
1940-41	Earl R. Glenn
1941-45	Anna M. Gemmill
1946-47	Victor L. Crowell
1947-48	Ellis Haworth
1948-49	H. Emmett Brown
1949-50	John Read
1950-51	George Haupt
1951-52	Robert Cooper
1952-53	Rose Lammel
1953-54	G. P. Cahoon
1954-55	Ned Bryan
1955-56	John Wells
1956-57	Robert Wickware
1957-58	June Lewis
1958-59	George Zimmer
1959-60	Harold Tannenbaum
1960-61	Herbert Schwartz
1961-62	Fletcher Watson
1962-63	Willard Jacobson
1963-64	R. Will Burnett
1964-65	Herbert Smith
1965-66	Ralph Lefler
1966-67	Edward Victor
1967-68	Sylvan Mickelson
1968-69	Stephen Winter
1969-70	Eugene Lee
1970-71	John Montean
1971-72	Paul Westmeyer
1972-73	Ronald D. Anderson
1973-74	Robert E. Yager
1974-75	David P. Butts
1975-76	Jacob Blankenship
1976-77	Patricia Blosser
1977-78	David H. Ost
1978-79	John Schaff
1979-80	Ertle Thompson
1980-81	Hans Anderson
1981-82	Jerry C. Horn
1982-83	James P. Barufaldi
1983-84	Ron W. Cleminson
1984-85	Thomas P. Evans
1985-86	Marvin Druger
1986-87	Robert K. James
1987-88	Joyce Swartney
1988-89	William C. Ritz
1989-90	Floyd Mattheis
1990-91	Gwendolyn Henderson
1991-92	Roger Olstad
1992-93	Catherine G. Yeotis
1993-94	Peter A. Rubba
1994-95	Norman Lederman
1995-96	Jim Ellis
1996-97	Paul Kuerbis
1997-98	Bill Baird
1998-99	Larry Flick
1999-2000	John Staver
2000-01	Julie Gess-Newsome

Award 4 – Innovation in Teaching Science Teachers

Previous Recipients

1990	A Reflective Approach to Science Methods Courses for Preservice Elementary Teachers	Dorothy Rosenthal
1991	Enhancing Science and Mathematics Teaching	Kenneth Tobin, Nancy Davis, Kenneth Shaw, & Elizabeth Jakubowski
1992	The Learning Cycle as a Model for the Design of Science Teacher Preservice and Inservice Education	Peter Rubba
1993	Reconstructing Science Teacher Education Within Communities of Learners	Deborah Tippins, Ken Tobin & Sherry Nichols
1995	Science for Early Adolescence Teachers (Science FEAT) A Program for Research and Learning	Samuel Spiegel, Angelo Collins, and Penny Gilmer
1996	An Innovative Model for Collaborative Reform in Elementary School Science Teaching	M. Gail Shroyer, Emmett Wright, and Linda Ramey-Gassert
1997	Reconceptualizing the Elementary Science Methods Course Using a Reflection Orientation	Sandra Abell & Lynn Bryan
1998	What the Science Education Standards Say: Implications for Teacher Education	Penny Hammrich

Early Morning Committee Work, Saturday 6:30–8:00 a.m.

6:30 - 8:00 a.m. *AETS Committee Meetings* Rooms TBA

Program --- ______________

Publications -------------------------------------- ______________

Awards -- ______________

Informal Education ------------------------------ ______________

Professional Liaisons ---------------------------- ______________

Concurrent Sessions, Saturday 8:00–9:00 a.m.

8:00 - 9:00 a.m. *Saturday, Session 1.1—Panel* City View North

Publishing in Science Education Journals

Sandra Abell, Purdue University; Craig Berg, University Wisconsin–Milwaukee; John Cannon, University of Nevada–Reno; David Crowther, University of Nevada–Reno; Charlene Czerniak, University of Toledo; Larry Enochs, University of Wisconsin–Milwaukee; Julie Gess-Newsome, University of Utah; Norman Lederman, Oregon State University

This session is designed to provide insight and advice on the process of publishing in science education journals. Representatives of several science education journals will participate in this panel.

8:00 - 9:00 a.m. *Saturday, Session 1.2—Panel* Salon C

What Does The Science Supervisor Expect Us To Teach Preservice Teachers Before They Enter The Science Classroom?

Jack Rhoton, East Tennessee State University; LaMoine Motz, Oakland (MI) County Schools; Jane Hazen Dessecker, Stark County (OH) Ed. Services Ctr.; Kathleen Sparrow, Akron City Schools; Monty Howell, Knox County (TN) Schools

A panel of science supervisors/systemwide leaders will discuss, from their perspectives, some of the qualities, knowledge, and skills that teachers of science should possess before they enter the science classroom.

8:00 - 9:00 a.m. *Saturday, Session 1.3—Papers* City View South

Science Education for All: Can We Achieve Educational Equity Without An Antiracist Critique?: Blackness and Whiteness in Science Teacher Education Programs

Mary Monroe Atwater, University of Georgia

This paper explores the ways teacher education programs can be structured so that students question schooling policies and practices, cope with race, and act so that all students learn quality science

Investigating Cultural And Linguistic Issues in Science Learning: From the Lens of Multicultural Children

Isabel Quita, San Francisco State University

This paper will explore and describe the linguistic and larger cultural components of multicultural students' ways of interpreting science phenomena.

Preparing Science Teachers to Cope with Continuously Evolving Diversity in the Classroom

Pamela Fraser-Abder, New York University

Strategies for empowering science teachers to cope with the continuously evolving diversity in their classes while increasing interest and achievement in science for all, are presented.

8:00 - 9:00 a.m. *Saturday, Session 1.4—Papers* City View East

What We Know About Our Future Math and Science Teachers

Patricia Morrell, University of Portland

Reports findings of a survey of preservice teachers, detailing their science and math backgrounds, strategies and technologies used in their math and science courses, etc.

Bridging the Gap: Supporting Secondary Science Teachers During Their Induction Years

Julie Luft, University of Arizona

During this session I will discuss the need for secondary science induction programs and share a collaboratively developed induction program for secondary science teachers.

The Long Term Impact of an Inquiry Based Science Class on Preservice Teachers

Alan Colburn, California State University Long Beach; Laura Henriques, California State University Long Beach

This study tested how an inquiry-oriented science course affected preservice teachers' attitudes and beliefs about science when the students later took a methods class.

8:00 - 9:00 a.m. *Saturday, Session 1.6—Demonstration (one hour)* Summit

Consideration of an Alternative Dissertation Format

Brian Gerber, Valdosta State University

Alternative formats to the traditional dissertation will be explored with an example of a journal ready style being presented.

8:00 - 9:00 a.m. *Saturday, Session 1.7—Interactive Session* Ohio

Using the Evaluation Standards to Assess Science Education Programs

Sandra West, Southwest Texas State University; Suzanne Shaw Drummer, Ohio State University

In this interactive session participants will become familiar with "The Program Evaluation Standards" by applying them to the improvement of mock science education programs.

8:00 - 9:00 a.m. *Saturday, Session 1.8—Interactive Session* Inventors

CyberBog- Extending the Interdisciplinary Inquiry that Starts With Field Trips

William Slattery, Wright State University; Susann M. Mathews, Wright State University

This session will share efforts to extend interdisciplinary investigations of a natural area by means of an internet web site archiving physical and biological data.

Concurrent Sessions, Saturday 9:20–10:20 a.m.

9:20 - 10:20 a.m. *Saturday, Session 2.1—Papers* City View North

The Nature of Science in Decision-Making: Lead Role, Supporting Character, or Out of the Picture?

Randy Bell, University of Virginia; Norman Lederman, Oregon State University

This investigation examined the roles of the nature of science and other factors in decision making on science and technology based issues.

Development of the Philosophies of Teaching and of Science for One MAT Science Intern

Carol Mueller, Harford County Schools; Michael Wavering, University of Arkansas

The proposed interactive panel session will look at reinventing, the science teacher from several perspectives: curriculum reform, professional development, multicultural education, and assessment and standards.

Improving Elementary Teachers' Conceptions of Nature of Science in the Context of a Science Content Course

Fouad Abd-El-Khalick, American University of Beirut

The present study assessed the influence of an explicit reflective approach implemented in a science content course on elementary teachers' conceptions of nature of science.

9:20 - 10:20 a.m. *Saturday, Session 2.2—Panel* Salon C

The Politics and Processes of State Science Standards Development: The California and Kansas Stories

Bonnie Brunkhorst, California State University San Bernadino; John Staver, Kansas State University

The Science Community Leadership for development of the California and Kansas Science Standards will present the processes by which two state standards were developed. Included in the discussion are implications for other states.

9:20 - 10:20 a.m. *Saturday, Session 2.3—Panel* City View South

Designing Video-Based Science Content Instruction For Elementary Teachers

Larry Flick, Oregon State University; Sandra Abell, Purdue University; Camille Wainwright, Pacific University; Anita Greenwood, University of Massachusetts at Lowell; Nancy Finkelstein, Harvard Smithsonian Center for Astrophysics

AETS has collaborated with the Science Media Group at the Smithsonian Astrophysical Observatory to produce a video-based instruction in science for elementary teachers.

9:20 - 10:20 a.m. *Saturday, Session 2.4—Panel* City View East

Creating Collaborations Among Science Teachers And University Science Educators In A Secondary Professional Development School (PDS)

Claudia Melear, University of Tennessee; Vidal Moreno, Becky Ashe, West High School

A panel of participants in the third year of a PDS will discuss how they are creating ways to collaborate in the preparation and induction of new teachers.

9:20 - 10:20 a.m. *Saturday, Session 2.5—Papers* Summit

Science as the Sacrificial Lamb: Confessions of Elementary School Teachers and Advice for Science Educators

Eileen Carlton Parsons, UNC-Chapel Hill

Eight elementary school teachers share reasons for omitting science instruction. They offer advice on what science educators can do to alleviate the sacrificing of science.

Science Education in an Urban Elementary School: Case Studies of Teacher Beliefs and Classroom Practices

Kenneth King, Northern Illinois University; Lee Shumow & Stephanie Lietz, Northern Illinois University

The study presents an investigation into discrepancies between teacher perceptions of practice versus observations of practice in an urban school.

Shifting Toward Inquiry Science Teaching: The Story of Secondary Science Teachers Working on Emergency Permits

Hedy Moscovici, California State University -Dominguez Hills

Based on a four-stage model developed previously, this study explores how secondary science teachers working on emergency permits teach science.

9:20 - 10:20 a.m. *Saturday, Session 2.6—Interactive Session* Airship

Autobiographical Genres in Educational Research: Considering the Legacies of Science Teacher Education in the Philippines

Sherry Nichols, East Carolina University; Deborah J. Tippins, University of Georgia; Joseph P. Riley, University of Georgia

This interactive session focuses on the use of autobiographical genres of educational research as tools for learning about the cultural myths and legacies of science teacher education in rural areas of the Philippines.

9:20 - 10:20 a.m. *Saturday, Session 2.7—Interactive Session* Ohio

Using and Creating Multicultural Nature Legends Across the Curriculum

Candace Miller, Ohio State University at Lima

Using legends as gentle teachers can capture attention and stimulate curiosity while linking science to other content areas. Also learn how to write your own.

9:20 - 10:20 a.m. *Saturday, Session 2.8—Demonstrations* Inventors

Technology Advancing a Continuous Community of Learners (TACCOL)

Vickie Harry, Clarion University of Pennsylvania

TACCOL implements an innovative environment for interfacing technology with mathematics and science education to achieve change in teacher education and K - 12 Learning.

Concurrent Sessions, Saturday 10:40–11:40 a.m.

10:40 - 11:40 a.m. *Saturday, Session 3.1—Panel* City View North

Science and Science Education Collaboratives: Where We Are, How We Got There, and Where We Are Going

Don Duggan-Haas, Kalamazoo College; Elizabeth E. Roettger, DePaul University; Dr. Gerald Foster, DePaul University; John R. Truedson, Bemidji State University; Cathy Yeotis, Wichita State University; Reneé S. Schwartz, Oregon State University; Norman G. Lederman, Oregon State University, Francie Rowe, Edgewood College; Paul Adams, Fort Hays State University

This is one of two connected presentations about collaborative projects between scientists and science educators. Participants will highlight obstacles faced and how obstacles are addressed.

10:40 - 11:40 a.m. *Saturday, Session 3.2—Panel* Salon C

A Benchmarks-Based Approach to Textbook Evaluation: Implications for Teacher Education

Jo Ellen Roseman, AAAS/Project 2061; Molly Hand Weinburgh, Georgia State University; Mary Ann Brearton, Project 2061–AAAS

Taking a benchmarks- and standards-based approach to textbook evaluation will have important consequences for teacher preparation and professional development programs.

10:40 - 11:40 a.m. *Saturday, Session 3.3—Demonstrations* City View South

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I'm Teaching, But They're Not Learning!

Nancy Finkelstein, Harvard-Smithsonian Center for Astrophysics

Ever wonder why students don't always learn what we teach them? Check out MINDS OF OUR OWN, a new documentary on how children "learn" science.

CASE in Point!

Nancy Finkelstein, Harvard-Smithsonian Center for Astrophysics

See real science teachers in action! Learn about CASE STUDIES IN SCIENCE EDUCATION, a new video series that takes education reform to a personal level.

10:40 - 11:40 a.m. *Saturday, Session 3.4—Papers* City View East

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Enhancing Preservice and Inservice Professional Development in Science Education Using the GLOBE Environment Science Curricula

Linda Ramey, Wright State University; James Tomlin, Wright State University

This presentation will describe incorporation of the GLOBE environmental science protocols and curricula into preservice and inservice teacher professional development.

An Investigation of a Professional Development Model in Science Education: A Systems Approach

Glenda Love Bell, Texas A&M University-Commerce; R. Lynn Jones Eaton, University of Texas at Austin

A systems approach was used to explore how this model affected elementary teachers' efficacy beliefs and behaviors toward science and inquiry-based science teaching.

GLOBE: Citizen Scientists with a Satellite Connection

Ruth Bombaugh, Cleveland State University

GLOBE puts into practice authentic learning, student-scientist partnerships, & inquiry-based pedagogy. Should science teacher education programs incorporate GLOBE certification as part of their curricula?

10:40 - 11:40 a.m. *Saturday, Session 3.5—Papers* Summit

Applying Interactive Computer Technologies in the Education of Prospective Elementary Teachers

Kenneth Tobin, University of Pennsylvania; Judith A. McGonigal, Curtin University of Technology

The study describes how asynchronous interactions facilitated the identification of critical issues in the teaching and learning of science and enhanced reflection on them.

An Undergraduate Science Laboratory Practicum for Pre-service Science Teachers

Jeffrey Weld, Oklahoma State University

An additional field experience for preservice science teachers has been arranged--as lab assistants in the Introductory Biology course at OSU. The program is being empirically analyzed.

Pre-Service Secondary Science Teachers' Concerns Regarding Calculator-Based Laboratory Probeware

David R. Wetzel, George Mason University; Gary F. Varrella, George Mason University

A study of pre-service secondary science teachers as they overcome their concerns regarding the use of Calculator-Based Laboratory probeware in their methods preparation courses.

10:40 - 11:40 a.m. *Saturday, Session 3.6—Papers* Airship

Preservice Science Teachers and Internet Telecommunication Tools: Issues to Consider

Alec Bodzin, The SERVIT Group, Lehigh University

This paper discusses important issues with using Internet telecommunication tools (Web-based forums, listservs, and e-mail) with preservice science teachers during their student teaching internships.

How Effective is the Use of the Internet in the High School Science Class in Metro Atlanta (Georgia)

Tom Howick, Kennesaw State University; Carol Mudd, Cherokee County Schools

This study will be conducted the Fall of 1999. The research instruments will be questionnaires and interviews with High School Science Teachers (urban, rural & suburban).

A Long Term Professional Development Program for Elementary and Middle School Science Teachers in Northern Minnesota

John Truedson, Bemidji State University

The results from a long term Professional Development project for K – 8 science teachers in Northern Minnesota will be presented along with the process for implementation.

10:40 - 11:40 a.m. *Saturday, Session 3.7—Interactive Session* Ohio

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Issues (and Non-Issues?) in Gender Equity in Preservice Science Teacher Education

David Jackson, University of Georgia

A critical discussion of gender equity concerns in preservice science teacher education, with particular reference to the relationship between male science teacher educators and female prospective teachers.

10:40 - 11:40 a.m. *Saturday, Session 3.8—Interactive Session* Inventors

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Integrating Technology into Science Methods Classes

Robert James, Texas A&M University; Caroline Beller, University of Arkansas; Joneen Hueni, Bellville High School; Patti Nason, Stephen F. Austin State University

Four strategies for integrating educational technology into science teacher preparation programs--Computer-Based Laboratories (CBL), Geographic Information System (GIS), graphing calculators and TrackStar will be demonstrated and compared to national standards.

Noon – 2:00 p.m. *Awards Banquet & Business Meeting* Salon A

Concurrent Sessions, Saturday 2:20–3:20 a.m.

2:20 - 3:20 p.m. *Saturday, Session 4.1—Panel* City View North

The 10th Anniversary of a Successful Elementary Science Teacher Preparation Program

Cherin Lee, University of Northern Iowa; Lisa Krapfl, University of Northern Iowa; Angela Stefan, University of Northern Iowa

The panel will describe and share ten years of experience with a successful, exemplary preservice elementary science preparation program.

2:20 - 3:20 p.m. *Saturday, Session 4.2—Panel* Salon C

Preparing Elementary Science Teachers To Support Children's Scientific Inquiry

Leigh Boardman, Penn State University; Tom Dana, Pat Friedrichsen, Joe Taylor, Carla Zembal-Saul, Penn State University

In this interactive symposium, presenters highlight ways in which content and pedagogy courses can synergistically support the development of preservice elementary teachers' understanding of scientific inquiry.

2:20 - 3:20 p.m. *Saturday, Session 4.3—Special Session* City View South

AETS 2000 Outstanding Paper Presentations

Deborah J. Tippins, Chair, AETS Awards Committee

2:20 - 3:20 p.m. *Saturday, Session 4.4—Papers* City View East

Updating Science Content Knowledge of High School Teachers - A Professional Development Model

Cynthia Geer, Xavier University

The dynamic nature of scientific knowledge creates a problem for high school science teachers who are trying to keep current in their specific fields. The professional model provides practical and successful means for assisting teachers to accomplish this goal

Electronic Concept Mapping As A Professional Development Focus For Health Sciences And Technology Academy (HSTA) Teacher-Participants

James Rye, West Virginia University

Electronic concept mapping is a current focus of science teacher professional development in a program that provides science enrichment and health careers orientation to underrepresented high school youth.

Constructing and Integrating a Six Phase Standards-Based Professional Development Model for the Education of Pre-Service Elementary Teachers of Science: Advancements of the Model During the First Three Years

George O'Brien, Florida International University; Scott P. Lewis, Florida International University

This presentation focuses on the description, theoretical background, and implementation status of a science education component of an undergraduate elementary teacher education program at a large, urban university

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2:20 - 3:20 p.m. *Saturday, Session 4.5—Demonstrations* Summit

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Multiple Strategies for Using Internet For Instruction

Craig Berg, University of Wisconsin-Milwaukee

Participants will use web-based modules that can be used to prepare in-service or pre-service teachers on how to use the Internet for teaching science with a focus on collaborative online projects and fostering productive interaction between classrooms.

Science Activities Manual: K-8, www edition

Maurice Houston Field, University of Tennessee at Martin

Demonstration of a free teacher written K-8 science program which uses the National Science Education Standards to define the Tennessee Science Curriculum Framework content topics.

2:20 - 3:20 p.m. *Saturday, Session 4.6—Interactive Session* Airship

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Science Education and Science Faculty Collaboration: Developing a Common Philosophy of Science Teaching

Robert Cohen, East Stroudsburg University; Gerald Wm. Foster, DePaul University; Mark Latz, University of North Carolina at Asheville; Don Duggan-Haas, Kalamazoo College; Chin-Tang Liu, Southwest Missouri State University; April Adams, Northeastern State University; Reneé S. Schwartz, Oregon State University

This is one of two connected presentations about collaborative projects between science and education faculty. Perspectives and documentation of philosophical teaching issues will be presented.

2:20 - 3:20 p.m. *Saturday, Session 4.7—Panel* Ohio

Examining K-8 Students' Views of Animals: A National Study

Charles Barman, IUPUI School of Education; Natalie Barman, IUPUI; Kay Berglund; M. Jenice Goldston, Kansas State University; Jamie D. Stockton, DePauw University

This presentation will discuss the interview protocol used in a national study to determine K-8 students' views about animals. Teaching strategies will be identified to help students refine their concept of animals.

2:20 - 3:20 p.m. *Saturday, Session 4.8—Interactive Session* Inventors

Issues in Urban Science Teacher Preparation

John Settlage, Cleveland State University; Paul Jablon, University of Massachusetts--Lowell

An open forum for fellow science teacher educators to discuss programs, resources, and issues related to preparing people to teach science in urban settings.

Concurrent Sessions, Saturday 3:40–4:40 a.m.

3:40 - 4:40 p.m. *Saturday, Session 5.1—Panel* City View North

Looking to the Future: Potential Changes in the Organizational Structure of AETS (2nd of 2 sessions)

Julie Gess-Newsome, President, AETS; John Staver, Kansas State University; Larry Flick, Oregon State University; Bill Boone, Indiana University --Bloomington

AETS started as a small group attending isolated sessions at NSTA. Is the current organizational structure responsive to our current needs? This session provides a forum to discuss proposed changes within AETS.

3:40 - 4:40 p.m. *Saturday, Session 5.2—Papers* Salon C

Sisters in Science: Teaching the Art of Inquiry

Penny Hammrich, Temple University; Greer Richardson, Temple University

The paper describes the changes in fourth grade teachers' conceptions of science/mathematics teaching and their perceptions of confronting the gender gap.

I Do Hands-On/Inquiry

Anita Roychoudhury, Miami University

Science instruction in urban schools shows that teachers consider any hands-on lesson as inquiry and low-income or poor students incapable of learning science.

What Teacher Educators Need to Know about Inquiry-Based Instruction

Alan Colburn, California State University Long Beach

This presentation, specifically for teacher educators, defines inquiry, reviews where research indicates it is and is not effective, and discusses classroom implementation of inquiry principles.

3:40 - 4:40 p.m. *Saturday, Session 5.3—Demonstrations* City View South

Preconceptions of Preservice Teachers about Planning Inquiry Science Lessons

Suzanne Weber, Oswego State University of New York; Diann Jackson, Oswego State University of New York

Methods students have preconceptions about teaching science which strongly influence their initial science lesson planning ideas and their subsequent understanding of inductive problem-solving science instruction.

Modeling Behaviors for Young Scientists: Video Technology as a Tool for Modeling Inquiry Skills

Kenneth King, Northern Illinois University; Thomas Thompson, Northern Illinois University

STARS–Students Thinking About Real Science–is a video-based staff development program developed by Northern Illinois University and the Elgin, Illinois school district to help elementary students develop inquiry skills.

3:40 - 4:40 p.m. *Saturday, Session 5.4—Papers* City View East

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Portfolio Assessment in Preservice Teacher Education

Steven Rakow, University of Houston-Clear Lake

This presentation describes a portfolio assessment for preservice teachers focusing on seven standards and using a rubric for evaluation. Public school teachers play a critical role

Utilizing a Participant-Centered Evaluation Plan in an Extended-Inquiry In-Service Program

Julie Luft, University of Arizona

During this session I will describe the development and use of a program-specific rubric that was utilized during an extended inquiry in-service program.

3:40 - 4:40 p.m. *Saturday, Session 5.5—Demonstrations* Summit

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Classroom Applications of Virtual Field Trips (Part 2)

Robert L. Hartshorn, University of Tennessee at Martin; J. Preston Prather, University of Tennessee at Martin; Janet Woerner, Cal. State, San Bernadino

Hardware and software tools help teachers develop and use their own Virtual Field Trips in classroom settings and help address issues of Internet access.

Imagineering and Inventiveness for Students and Teachers

Alan McCormack, San Diego State University

A rationale for including attention in school science curricula to development of students' and teachers' creativeness will be buttressed through demonstration of Imagineering lessons.

3:40 - 4:40 p.m. *Saturday, Session 5.7—Highly Interactive* Ohio

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AETS 2001 Planning Meeting

Kathy Norman, California State University San Marcos

6:30 p.m. *Saturday —Buffet Dinner, Tickets required ($25)* City View East

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Women in Science Education

Open to all who are interested in issues for women in science education.

Special Session, Sunday 9:00-11:00 a.m.

9:00 – 11:00 a.m. *Sunday, General Session* City View East

Dialogue between the Glenn Commission and the AETS Membership

Emmett Wright, Director of Research, National Commission on Mathematics and Science Teaching for the 21st Century

Learn about the goals of the Commission to develop recommendations for public policy to set new directions for the support of science and mathematics education in the 21th Century. AETS members will have the opportunity to communicate their ideas to representatives to the Commission. Input from AETS members will be summarized and reported to the entire commission.

Award 5 – Implications Of Research For Educational Practice

1981 Wait-time and Learning in Science — Ken Tobin & Bill Capie, Western Australian Institute of Technology & University of Georgia

1983 The Disadvantaged Majority: Science Education for Women — Jane Kahle , Purdue University

1984 Training Science Teachers to Use Better Teaching Strategies — Russel H. Yeany & Michael J. Padilla, The University of Georgia

1985 Using Research to Improve Science Teaching Practice — Kenneth Tobin , Western Australian Institute of Technology

1986 Active Teaching for Higher Cognitive Level Learning in Science — Kenneth Tobin, Willian Capie, & Antonio Bettencourt, The University of Georgia

1987 Training Teachers to Teach Effectively In The Laboratory — Pinchas Tamir , The Hebrew University of Jerusalem

1988 What Can Be learned From Investigations of Exemplary Teaching Practice — Kenneth Tobin & Barry J. Fraser, Florida State University & Curtin University of Technology

1989 Visual/Spatial Thinking: An Essential Element of Elementary Science — Alan J. McCormack, San Diego State University

1990 Helping Students Learn How to Learn: A View from a Teacher-Researcher — Joe Novak, Cornell University

1991 An Expanded View of the Learning Cycle: New Ideas About an Effective Teaching Strategy — Charles R. Barman, Indiana University

1992 Teacher Development in Microcomputer Usage in K-12 Science — James D. Ellis, BSCS

1993 Understanding and Assessing Hands-on Science — Larry Flick, Washington State University

1994 Teaching Evolution: Designing Successful Instruction — Lawrence Scharmann, Kansas State University

1995 Using Visits to Interactive Science and Technology Centers, Museums, Aquaria, and Zoos to Promote Learning in Science — Leonie Rennie & Terrence McClafferty, Curtin University

1996 General Biology: Creating a Positive Learning Environment for Elementary Education Majors
Larry Scharman & Ann Stanheim-Smith, Kansas State University

1997 Empowering science teachers: A model for professional development — Ann Howe & Harriet Stubbs of Raleigh, North Carolina & North Carolina State University

1998 A Dynamical Systems Based Model of Conceptual Change — Andrew Hurford, Haskell Indian Nations University

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A QUANTITATIVE EXAMINATION OF TEACHER SELF EFFICACY AND KNOWLEDGE OF THE NATURE OF SCIENCE

Sajin Chun, University of Georgia
J. Steve Oliver, University of Georgia

The importance of an understanding about the nature of science has persisted over the past century among general educators as well as science educators (Dewey, 1933; Downing, 1925; Lederman, 1992; Munby & Roberts, 1998). There is no consensus on the meaning and the use of the nature of science presently among different groups of science community such as scientists, philosophers of science, and science educators. One of the major views is shaped by considerations of the nature of science as epistemology and expressed as "a way of knowing." This view is frequently associated with instructional goals which aim to increase intellectual independence of learners (Munby and Roberts, 1998). Also, the nature of science has generally been used to refer to values and beliefs inherent to the development of scientific knowledge (Lederman, 1992).

In recent decades, there is an increased interest in the structure of teacher knowledge and beliefs for both preservice and inservice science teachers (Kagan, 1992; Pajares, 1992; Polmeroy, 1998; Shulman, 1986, 1987). Lee Shulman (1987) has proposed a typology of the "knowledge bases of teaching" which suggests a multifaceted structure rather than viewing teaching as a skill of transferring certain ideas to students. This model requires teachers to understand and to teach for understanding.

> Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing and how it relates to other propositions, both within the discipline and without, both in theory and in practice (Shulman, 1986, p. 9).

Exploring teachers' beliefs about science and science teaching has become an extremely popular topic in the science education area in recent years. Numerous classroom based studies have been conducted to investigate teachers' beliefs about science and science teaching (Duschl and Wright, 1989; Gallagher, 1991; Brickhouse, 1990, Lederman and Zeidler, 1987; Palmquist and Finley, 1997; Lorsbach, 1992; Abell and Smith, 1994; Pomeroy, 1993; Laplante, 1997; Abd-El-Khalick, Bell, & Lederman, 1998). In spite of numerous studies conducted previously, there is no consensus regarding the assumption of whether there is a relationship between teacher beliefs about the nature of science and other effects, such as teacher efficacy beliefs, teacher beliefs about science teaching, and actual teaching practices. Unfortunately, many of previous study results have shown that both preservice and inservice teachers do not have appropriate levels of understandings about the nature of science (Duschl & Wright, 1989; Gallagher,1991).

The main problem of getting teachers to teach the nature of science might lie in difficulties of grasping appropriate levels of knowledge about the nature of science. Yet, another difficulty might come from the distinctive character of teacher beliefs about the nature of science and other effects of the beliefs. Therefore, it is important to understand how teachers' knowledge of the nature of science and efficacy beliefs of science teaching have been changed and to what extent the knowledge of the nature of science and teacher efficacy beliefs are interrelated with each other.

The purpose of this study is to investigate the process of change in teacher knowledge and beliefs with regard to the nature of science and teacher efficacy beliefs about their science teaching. All participants took part in three summer workshops over a three year period, and thus the data is longitudinal. This study is intended to provide the evidence which illustrates the change in congruency of teacher beliefs throughout the time period of the workshops. Research questions are: (a) how did the teacher beliefs about the nature of science and efficacy beliefs about science teaching change during the summer workshops; and (b) to what extent were the teachers' knowledge of the nature of science interrelated to the efficacy beliefs about their science teaching practices.

Four sets of quantitative data were collected repeatedly from a group of middle school science teachers who participated in a sequence of three years summer workshops from 1994 to 1996: *the Nature of Scientific Knowledge Scale* (Rubba & Anderson, 1978), *the Science Teacher Efficacy and Belief Inventory* (Enochs, L. G., Scharmann, L. C., & Riggs, I. M., 1995), *the Stage of Concern* (Hall, George, & Rutherford, 1979), and *How Can You Know* (Oliver, Crockett, Elliott, Butts, & Chun, 1997). The workshops were designed to enhance middle school teachers' understanding about the nature and structure of science as well as pedagogical knowledge to teach science. Descriptive statistics were applied to analyze those data in order to present the trends and patterns in the change of teacher beliefs. Pearson correlation coefficient and a frequency distribution table were used to examine the relationship between teacher knowledge of the nature of science and teacher efficacy beliefs in science teaching.

Literature Review

Current science education reform identifies the nature of science as an important criterion to describe a scientifically literate person (AAAS, 1989, 1993; NRC, 1996). To accomplish the goal of scientific literacy for all, science instruction is often suggested to include current views about the nature of science. One of most frequent characterizations of the nature of science is to consider it as an epistemology and this is expressed as "a way of knowing" and used to increase intellectual independence of learners (Munby and Roberts, 1998). According to Munby and Roberts (1998), experiences with the "reasoned nature of science" can develop students' intellectual independence by including "such matters as the importance of evidence, the considerations of alternative views, and the basis on which ideas are judged to be acceptable or not acceptable" (p. 103). Likewise Lederman (1992) has suggested the nature of science also can be referred to as values and beliefs inherent to the development of scientific knowledge. Abd-El-Khalick and Lederman (1998) recently suggested that there were a general level of characteristics of the scientific enterprise considered to be applicable to school science teaching: (a) tentative (subject to change), (b) empirically-based (based on and/or derived from observations of natural world), (c) subjective (theory-laden), (d) necessarily involves human inference, imagination, and creativity, and (e) is socially and culturally embedded.

In recent time, there have been increased interests about the structure of teacher knowledge (Shulman, 1986, 1987; Mellado, 1998) and beliefs (Kagan, 1992; Pajares, 1992) and teacher beliefs have become one of the most popular topics in the science education area. Both Pajares (1992) and Kagan (1992) view that beliefs are a subject of legitimate inquiry in studying teachers' ways of thinking and classroom practices where attitude and values have long been a focus of social and personality research. Lee Shulman (1987) described the "knowledge bases of teaching" in terms of seven components rather than viewing teaching as a skill of transferring certain ideas to students. Those seven categories of the knowledge bases include as follows: (a) content knowledge; (b) general pedagogical knowledge; (c) curriculum knowledge; (d) pedagogical content knowledge; (e) knowledge of learners; (f) knowledge of educational contexts; and (g) knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Among those categories, pedagogical content knowledge (PCK) is of special interest and was defined as "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8). In other words, the PCK is a type of knowledge that is unique to teachers, and is based on the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge. This description requires us to understand the elements of teacher knowledge, beliefs and functions of the knowledge in teaching practices.

In spite of numerous studies conducted previously, there is still lack of consensus on the results from the research examining the assumption that if there is the relationship between teacher beliefs about the nature of science and other beliefs or teaching practice. Unfortunately, many of previous study results have shown that both preservice and inservice teachers do not have an appropriate level of understandings about the nature of science. For instance, Gallagher (1991) found that "these teachers were unable to articulate a deep, coherent understanding of the nature of science" (p. 127). Moreover, secondary science teachers have been shown to have a distorted understanding of the nature of science because their scientific education has focused on the body of knowledge of science, and it has given very little emphasis to the processes by which scientific knowledge is developed and validated. Agreeing with this statement and taking the idea a step further, Lederman and Zeidler (1987) found that simply possessing valid conceptions of the nature of science does not necessarily result in the performance of those teaching behaviors which are related to improving student conceptions.

On the other hand, there is an another view that the understanding of nature of science is directly related to other effects, such as teacher beliefs about science teaching (Abell & Smith, 1994) or actual science teaching practices (Brickhouse, 1990; Palmquist & Finley, 1997). Abell and Smith (1994) suggested that the preservice teachers' views about the nature of science are closely tied to their beliefs about teaching and learning. The preservice teachers hold naive realist views of science that see science as a process of discovering what is out there, not as a human process of inventing explanations. So the student teachers failed to see the importance of the learners' physical, cognitive, and social activities in making sense of the world. Palmquist and Finley (1997) also concluded that the post-baccalaureate preservice teachers' views of science mostly matched the views that were portrayed in their teaching. In this study, the researchers argued that the preservice teachers' initial view of the nature of scientific method was traditional and their classroom practice was also traditional. Their results suggest that as the preservice teachers' views move to becoming fairly contemporary during the teacher education program, their teaching practice also moves toward becoming fairly contemporary.

Brickhouse (1990) examined whether there is a relationship between teachers' beliefs about the nature of science and their teaching practices. Her case study of three inservice teachers shows that the teachers differed in their views on the nature of scientific theories, scientific processes, and the development of the scientific knowledge. The teachers' beliefs about science did influence the form of science classroom instructions. Differences appeared, for example, in the questioning patterns of each teacher and applying problem solving strategy in science teaching.

Because of methodological difficulty of capturing teacher knowledge and beliefs, it is not easy to provide empirical evidences to support the interrelationships among the different constructs of teacher beliefs. Yet, it is important to know how different constructs of teacher knowledge and beliefs are interrelated to one another in order to understand the dynamic teacher belief system.

Rationale

Studies of teacher beliefs are suggested as becoming one of the most valuable psychological constructs of teacher education in a field where attitudes and values already have been the prevailing constructs (Pajares, 1992). However, according to Pajares (1992), the implicit interest and fascination about teacher beliefs of educators and researchers has not focused explicitly on the implications for either educational practice or research. To find out the practical implications, empirical based research should be conducted to provide evidences.

Although there have been numerous studies to attempt to understand the various aspects of teacher knowledge and beliefs about the nature of science, evidence has not clearly been shown to support the claim for teacher knowledge about the nature of science with regard to increasing teachers' self efficacy in science teaching as well as to enhancing the quality of science instruction. From the previous research review, difficulties in investigating teacher knowledge and beliefs about the nature of science and science teaching were identified: (1) methodological problems in identifying a person's beliefs/knowledge accurately because of the implicit and complex nature of beliefs, (2) confusing definitions of beliefs, including the distinction between beliefs and knowledge, (3) difficulties in understanding the ideas of the nature of science for both preservice and inservice teachers, (4) practical problems such as the lack of explicit resources in teaching the nature of science at school, and (5) constraints, such as other priorities or extra teaching loads which minimize time for reflecting on the nature of science and its relevance to science teaching.

There has been an assumption that teachers' knowledge of the nature of science relate to other effects or functions such as beliefs about science teaching and teaching practices. However, there is lack of concrete evidence to show the relationships in previous research. Therefore it is the rationale of this study to provide empirical evidences to show the process of change in teacher knowledge and beliefs and to examine the relationships among the different components of teacher knowledge and beliefs by analyzing the longitudinal data measured in a quantitative way.

Purpose Statement

The purpose of this study is to investigate the process of change in teachers' knowledge about the nature of science and teacher efficacy beliefs about teaching during a three-year sequence of summer workshops. This study is intended to provide empirical evidences that illustrate the change in congruency of teacher knowledge of the nature of science and the teacher efficacy beliefs throughout the time period of the workshop.

Research Question

Guiding research questions are as follows:

1. How did the teachers' knowledge about the nature of science, the efficacy beliefs, and the concerns about their science teaching change during the three-year summer workshops?
2. To what extent were the teachers' knowledge of the nature of science and scientific discovery interrelated to the teachers' self efficacy beliefs and concerns about science teaching?

Methodology

During a sequence of three-year summer workshops conducted during 1994, 1995, and 1996, quantitative data was collected. Descriptive statistics were applied to analyze those data by using the SAS program (SAS Institute Inc., 1989). Because of the small number of participants, researchers didn't attempt to conduct further statistical testing. The main purpose of this study was to present the trends and patterns in the change of interrelationship among different constructs of teacher beliefs, Pearson correlation coefficient and frequency distribution tables were used to show the relationships between teacher efficacy belief and knowledge of science. A purposeful sample of 31 middle school science teacher was drawn from the 8 school districts located in southeastern part of the U.S. All participant teachers had over 5 years of teaching experience as a science teacher at the beginning of the workshop.

Data Collections

During a sequence of three-year summer workshops, both quantitative and qualitative data were collected to identify the changes in the science teachers' knowledge about the nature of science and their beliefs about science teaching. Four sets of quantitative data were collected repeatedly during the workshops as pre- and post-test format: *the Nature of Scientific Knowledge Scale* (Rubba & Anderson, 1978), *the Science Teacher Efficacy and Belief Inventory* (Enochs, L. G., Scharmann, L. C., & Riggs, I. M., 1995), *the Stages of Concern* (Hall, George, & Rutherford, 1979), and *How Can We Know* (Oliver, Crockett, Elliott, Butts, & Chun, 1997). With those data, open-ended type written responses about the How Can We Know were collected at the end of the whole workshops. Also interviews with individual participant teachers were conducted by outside persons who were responsible for the evaluation for this project.

Instruments

The Nature of Scientific Knowledge Scale (NSKS)

Rubba and Anderson (1978) constructed the 48 items that are randomly arranged to form the Nature of Scientific Knowledge Scale (NSKS). Sample items are provided in Table 1. Subscales are composed from the eight items, four positive and four negative, corresponding to each of the factors in a Model of the Nature of Scientific Knowledge, i.e., amoral, creative, developmental, parsimonious, testable and unified subscales. Subscale scores were calculated by summing the appropriate 8 items of a given subscale after reflecting the negative items of the scores. Following this scoring scheme, a maximum score of 40 points for each subscale and 240 points for the entire NSKS is possible.

Table 1

Sample Items in the Nature of Scientific Knowledge Scale

Subscale	Sample Items
Amoral	It is incorrect to judge a piece of scientific knowledge as being good or bad.
Creative	Scientific theories are discovered, not created by man.
Developmental	Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence.
Parsimonious	Scientific knowledge is stated as simply as possible.
Testable	A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.
Unified	Biology, chemistry, and physics are similar kinds of knowledge.

The NSKS instrument was administered five times throughout the three-year summer workshop which provide pretest and posttest at the 1994 workshop, pretest and posttest at the 1995 workshop, and posttest at the end of the 1996 workshop.

How Can You Know (HCYK)

The HCYK instrument was developed to identify the level of knowledge that teachers possessed relative to teaching about scientific process knowledge called "How Can You Know" during the workshop. It contains 22 items with each item representing a specific science concept. Teachers responded to the items with three different scores (1: some knowledge about how we know with regard to the concept, 2: level of knowledge that can provide the specific examples of HCYK strategy with regard to the concept, 3: level of ability to provide an example of teaching the concept with HCYK strategy and of willingness to teach). The HCYK instrument was administered three times, pretest and posttest at the 1994 workship and pretest at the 1995 workshop.

The Science Teacher Efficacy and Belief Inventory (STEBI)

The STEBI instrument was determined to be an effective instrument to measure teachers' efficacy beliefs about science teaching (Enochs, L. G., Scharmann, L. C., & Riggs, I. M., 1995). It contains 25 items (1-5 Likert scale) that make two sub constructs of teacher beliefs labeled "self efficacy" and "outcome expectancy." Self-efficacy is a measure of the degree to which a science teacher believes that they can succeed in teaching science. Outcome expectancy is a measure of the degree to which a science teacher expects their students' outcome to succeed as a result of their teaching. The STEBI instrument was also administered five times throughout the three-year summer workshop: pretest and posttest at the 1994 workshop, pretest and posttest at the 1995 workshop, and posttest at the end of the 1996 workshop.

The Stages of Concern (SoC)

The SoC instrument was used to decide the level of concern with regard to an "innovation" (Hall, George, & Rutherford, 1979). The instrument includes seven categories of concern labeled as Awareness, Informational, Personal, Management, Consequences, Collaboration, and Refocusing scored by 1-7 scale. The SoC data were collected 4 times throughout the whole workshop, pretest and posttest at the 1994 workshop, posttest at the 1995 workshop, and posttest at the 1996 workshop.

Data Analysis

Descriptive statistics were calculated to analyze the data collected from implementation of the four quantitative instruments. Because of the small size of the completed data set after eliminating the missing data, experimental testing could not be conducted but descriptive statistics generated. By analyzing means and standard deviations of the each instrument administered repetitively throughout the workshop, it is intended to provide the evidences of change in the teachers' knowledge about the nature of science and their beliefs about science teaching during the three years workshop.

Findings

By analyzing means and standard deviations of the instruments administered repetitively throughout the workshop, it is intended to show the change in the participant teachers' knowledge about the nature of science and their efficacy beliefs about science teaching during the three-year-workshop. In order to examine the degree of relationships among different aspects of teacher knowledge and beliefs that include the teachers' knowledge about the nature of science, the knowledge about the How Can You Know, the teacher efficacy beliefs, and the level of concerns about science teaching with regard to an innovation, Pearson correlation coefficients and frequency distribution table were calculated.

The Change in the Teachers' Knowledge about the Nature of Science and Their Beliefs about Science Teaching

Means and standard deviations of the instrument scores which were administered repeatedly for three years of summer workshops were examined to provide the evidences for the patterns of change in the teachers' knowledge of the nature of science and efficacy beliefs about science teaching.

The Nature of Science

Across the five data collections, the mean scores of the participants' responses increased in each subscale, but not in significant amounts of changes (see Figure 1). The initial measurement shows that the participants already hold an adequate level of scientific knowledge. The subscale labeled "Testable" was the highest score both in initial and final tests (from 4.41 at the initial test to 4.55 at the final test). The second highest subscale was "Development" which changed from 4.26 to 4.38. The lowest scored subscale was "Parsimonious" which recorded the lowest score in both initial and final test results: 3.39 and 3.64 at each.

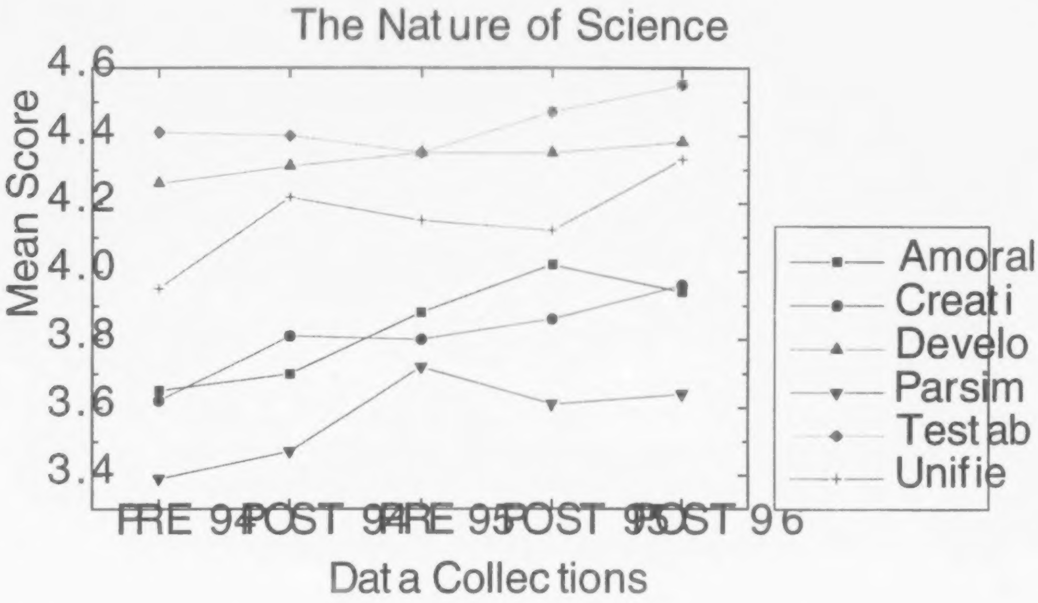


Figure 1. The change in the level of teacher knowledge about the nature of science during the summer workshops (1994-1996).

The subscales called "Creative" and "Unified" presents the largest amount of changes in the mean scores between initial and final tests (0.34 and 0.38 at each). The subscales which shows the first and second highest mean scores throughout the tests presents the subscales which has minimal increases in their score throughout the workshop. This data analysis suggests that: (a) teacher beliefs are not easily changed, and (b) initial level of teacher knowledge can affect the amount of changes in teacher beliefs.

The Science Teacher Efficacy and Beliefs Inventory (STEBI)

Throughout the five data collections over three years summer workshops, the scores of self efficacy and outcome expectancy shows increases and were parallel to each other (see Figure 2). In each subscale variable, the participants show a gain during the course of the first workshop. But when the teachers returned for the second year workshop, the scores were decreased. This is regarded as a common pattern after working with children at school after the workshop, (i.e. they realized the difficulties in teaching the innovation) (Oliver et. al., 1997).

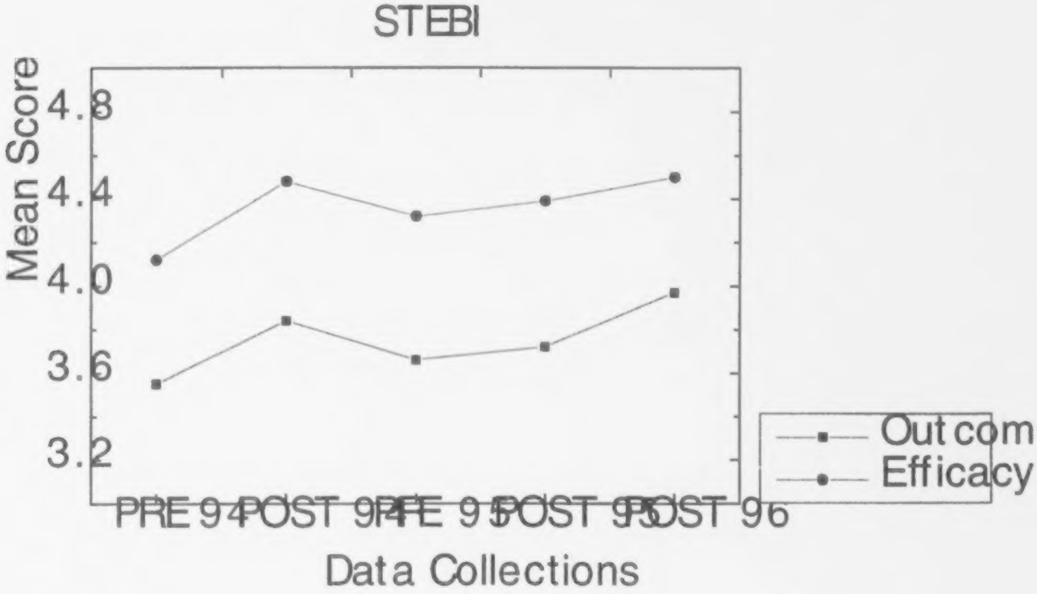


Figure 2. The change in teacher efficacy beliefs during summer workshops (1994-1996).

At the third year workshop the instrument was not administered at the beginning of workshop because the third workshop was only 2 weeks in duration. Therefore the figure does not represent the exact pattern of changes in teacher beliefs, however it shows increasing values of teacher efficacy beliefs during each administration of the instrument.

How Can You Know (HCYK)

The HCYK instrument was administered three times, pretest and posttest at the 1994 workshop and pretest at the 1995 workshop. According to the data, very few participants indicated a substantial knowledge of 'how can we know' with regard to the instrument at the pretest of the 1994 workshop. The mean score for the HCYK at the pretest of 1994 was 11.3. This means that the participants had some knowledge of HCYK with regard to only the half of items among the total 22 items in the instrument. In each item of the HCYK, the participants responded in a quantitative way: '1 = having some knowledge about how we know', '2 = not only having some knowledge of how we know but also knowing examples of how we know', and '3 = Not only pretty concrete knowledge about how we know but also having willingness to implement the idea in their teaching practices'.

By the end of the workshop of the first year, many participants showed that they not only had knowledge of how we know with regard to most of the items, but also indicated a willingness to teach these concepts. This was indicated by the mean score of 24.0 at the posttest of the 1994 workshop (see Figure 3). A continuous data collection had not been done, but this figure can provide the teachers' knowledge growth during the workshop.

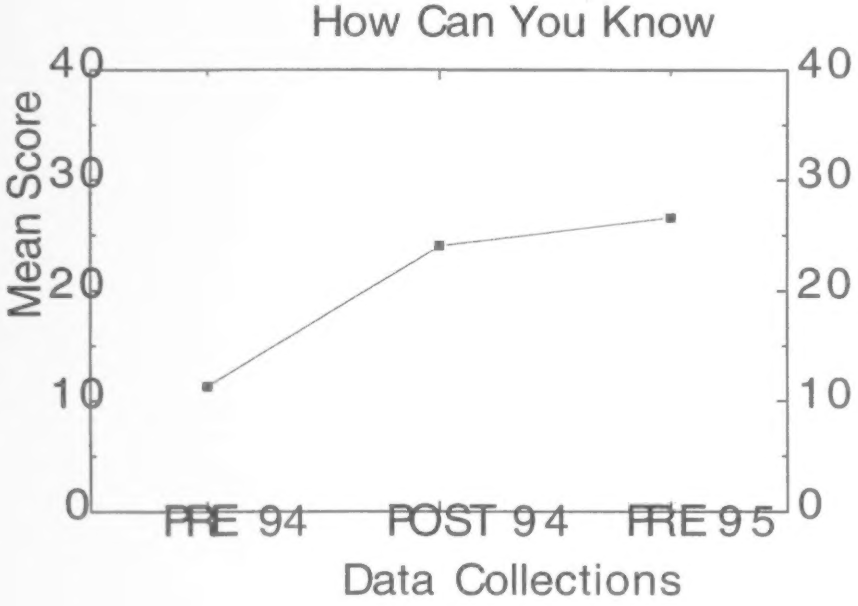


Figure 3. The change in teacher knowledge about the How Can You Know (1994-1995).

The Stages of Concern (SoC)

The SoC instrument was administered four times, the pretest and posttest at the 1994 workshop, the posttest at the 1995 workshop, and the posttest at the 1996 workshop. The SoC instrument was used to identify teachers' level of concern with regard to an "innovation" which was described as "teaching middle school science using the nature of science and how we know strategy" in these workshops.

The initial data collection (see Figure 4) indicated that three components of concern were rated high. They were informational, personal, and collaboration with the mean values of 88.9, 82.0, and 85.5 in the percentile scores respectively. The highest concern was about the availability of information to help teaching about the nature of science. At the end of the three year summer workshops, informational and personal concerns were diminished with the values of 63.4 and 50.9 respectively. However, the concern of collaboration persisted throughout the whole workshop and the value was increased to 90.2 at the end of the 1996 workshop.

The four other concerns, awareness, consequences, management, and refocusing indicated lower initial levels with values of 68.2, 54.6, 59.2, and 64.6. The data could not represent exact patterns of change in concern level during the three years workshop. However, it represent that two of those four concerns, consequences and refocusing, were increased at the end of the first year workshop and stayed at that level throughout the workshop. The others, awareness and management concerns were decreased at the end of the first year workshop, and remained at pretty much the same level of concern throughout the subsequent workshop.

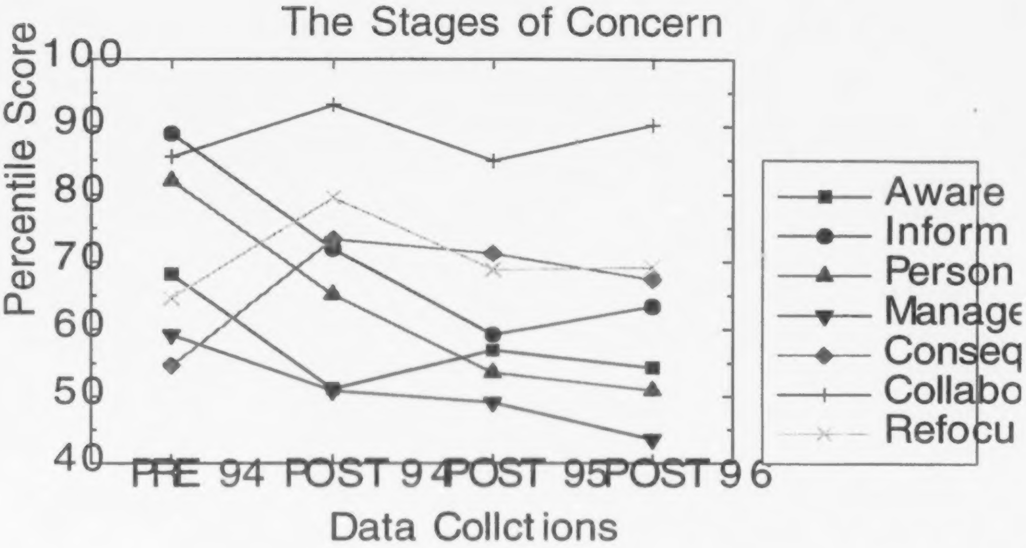


Figure 4. The change on the level of teacher concerns about the innovation during workshops (1994-1996).

The Relationships Among Teacher Knowledge of the Nature of Science, Teacher Efficacy Beliefs, and Concerns about Science Teaching

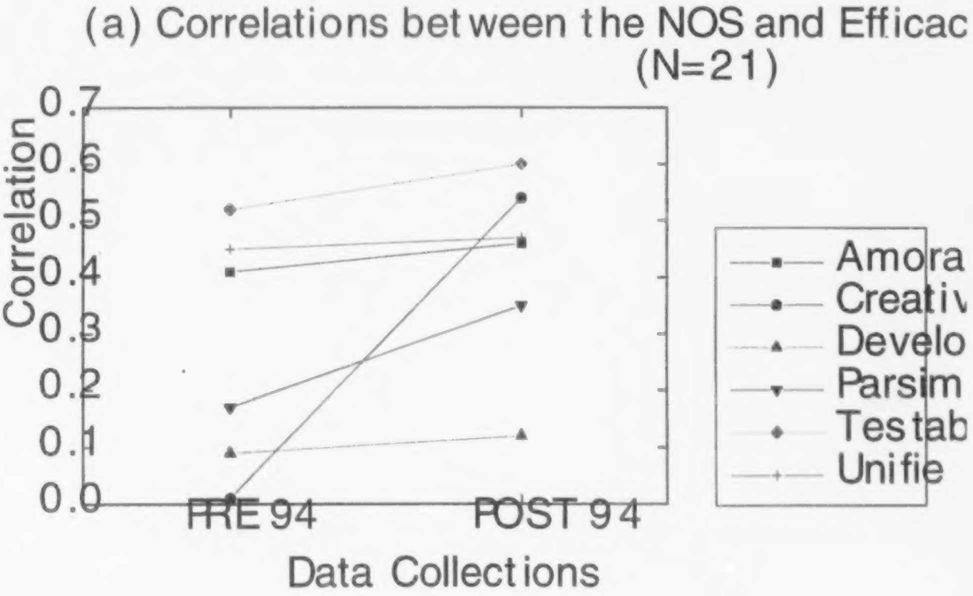
The researchers attempted to examine the change in the level of congruency between different constructs that included teacher knowledge about the nature of science and how can you know, teacher efficacy beliefs, and concerns during a sequence of three years summer workshops. Given the small subject number of the complete data set (N=18), a significance testing design was not applied. However, it was attempted to examine the relationships among the different constructs by considering Pearson correlation coefficients and frequency tables among different instruments' scores at each year of the workshop.

The NOS and the STEBI

The data analysis result didn't provide the exact patterns of change in the relationship between teacher efficacy beliefs and knowledge of the nature of science during workshops.

However, two subscale scores of the NOS instrument labeled "Testable" and "Unified" had positive correlations with the STEBI instrument scores during the workshop period of 1994 and 1995 with the range of 0.25 ~ 0.81 (see Figure 5). The positive correlation values show that the participants who have high mean scores of the NOS tends to have high self-efficacy beliefs.

And also, the data analysis result does not provide consistent results in all subscales of the Nature of Science. For example, the "Developmental" subscale did not indicate a significant correlation with teacher efficacy belief construct throughout the workshop. Some of the correlation values between a subscale of the NOS and STEBI tend to show increasing patterns within workshop periods. Yet, there were also decreasing patterns of the correlations during the workshop period (e.g., "Parsimonious" and "Unified" concepts at the 1995 workshop).



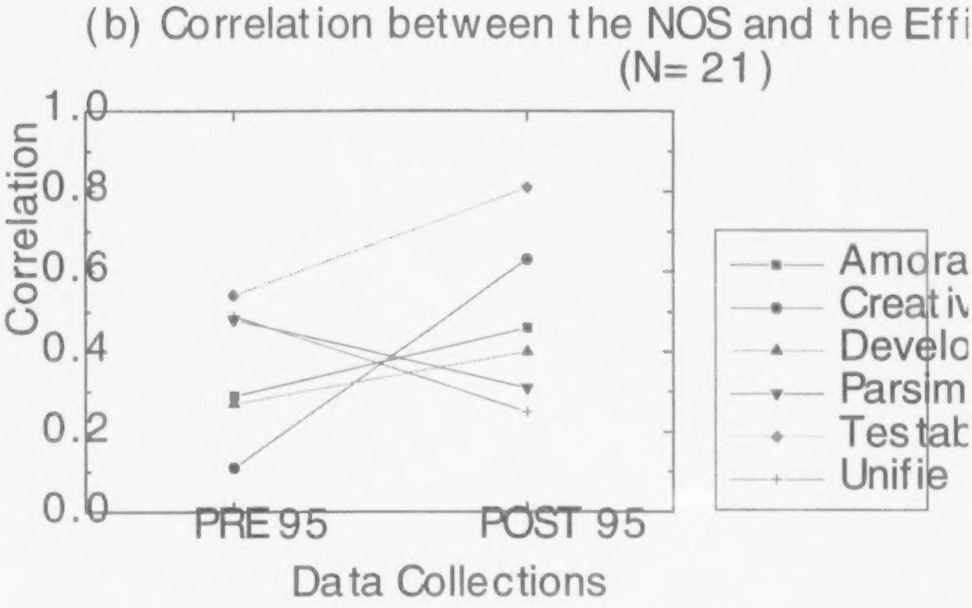
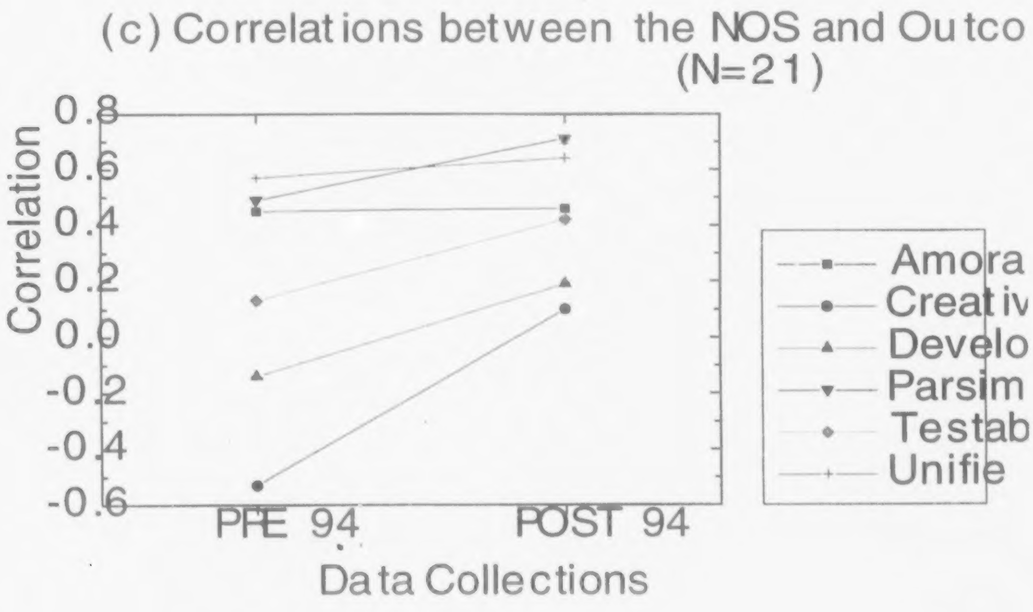


Figure 5. The correlation between the teacher knowledge of the nature of science and the teacher efficacy beliefs about science teaching.



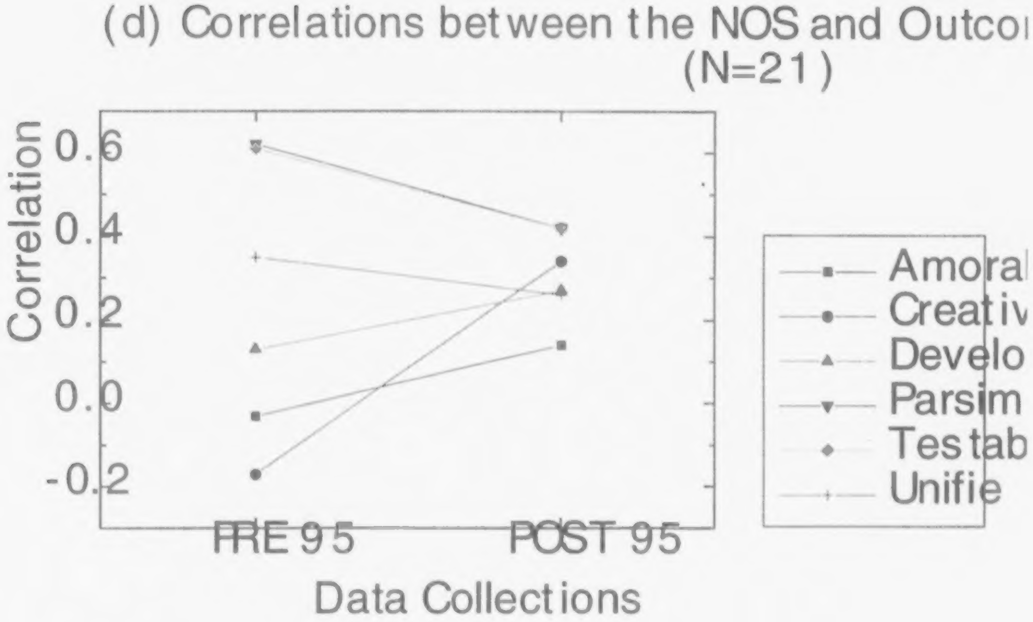


Figure 5. The correlation between the teacher knowledge of the nature of science and the teacher efficacy beliefs about science teaching.

As another way to examine the relationships between the different constructs, frequency distribution tables were built based on the ordinary type data sets which were converted from the original score to three hierarchical grouping numbers. The labels of the groups (A, B, and C) in each instrument represent low, medium, and high levels of group based on the range of the original score in the instruments. Table 2 presents the criteria of assigning the level of grouping.

Table 2

Criteria of Assigning the Level of Groups

Instrument	Subscale	Group	Range of the Score
NOSK	Testable	A	LT 4.0
		B	GE 4.0 and LT 4.5
		C	GE 4.5
	Creative	A	LT 3.5
		B	GE 3.5 and LT 4.0
		C	GE 4.0
STEBI	Self Efficacy	A	LT 4.0
		B	GE 4.0 and LT 4.5
		C	GE 4.5
	Outcome Expectancy	A	LT 3.5
		B	GE 3.5 and LT 4.0
		C	GE 4.0
HCYK		A	LT 15
		B	GE 15 and LT 30
		C	GE 30

Based on the criteria described above, data were converted to categorical values and a frequency table was built based on the grouping. Table 3 represents the frequency distribution that attempts to present the relationship between the teachers' knowledge of the NOS and efficacy beliefs. The number of each cell represents the number of participant in the level of group. The numbers of the diagonal component cells in the frequency distribution table represents that there is a meaningful relationship between two variables. Though there were not a large number of subjects, it seems to provide a positive relationship between the knowledge of the nature of science and the STEBI especially among the group A and C, which represent the low and high scored group respectively with regard to the HCYK scores. This result looks consistent with the correlation coefficient analysis result.

Table 3

Frequency Distribution Table of the Posttest of 1994.

			HCYK: Group A						HCYK: Group B						HCYK: Group C					
			STEBI						STEBI						STEBI					
			SE			OE			SE			OE			SE			OE		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
		A		1		1				2				2						
	T	B	1				1		1	2	1	3	1			1			1	
N		C		1	2			3	1		3	1	1	2			2	1	1	
O		A							1	1		2								
S	C	B	1		1		1	1	1	2	2	1		4			1		1	
		C		2	1	1		2		1	2	1	2			1	1	1	1	

The HCYK and the STEBI

The correlation between the HCYK and the "Self Efficacy" scale of the STEBI instrument indicated that positive correlations ranged from 0.28 at the pretest of 1994 to 0.49 at the pretest of 1995 (see Figure 6). Because the HCYK data were only collected the first three times, it is not enough to conclude that the relationship between teacher efficacy beliefs and knowledge of the How Can You Know tends to grow during the workshops. It can only tentatively suggest that as teachers felt more comfortable to use their knowledge of how we know, teachers became more confident about their teaching with the benefit of participating the workshops.

However, the "Outcome Expectancy" scale did not provide evidences to support a significant correlation between the HCYK score and teacher efficacy belief. It may represent that even though teacher felt more comfortable and confident on their own development during the workshop, their beliefs about students' learning outcome as a consequence of learning HCYK still remain at a questionable level.

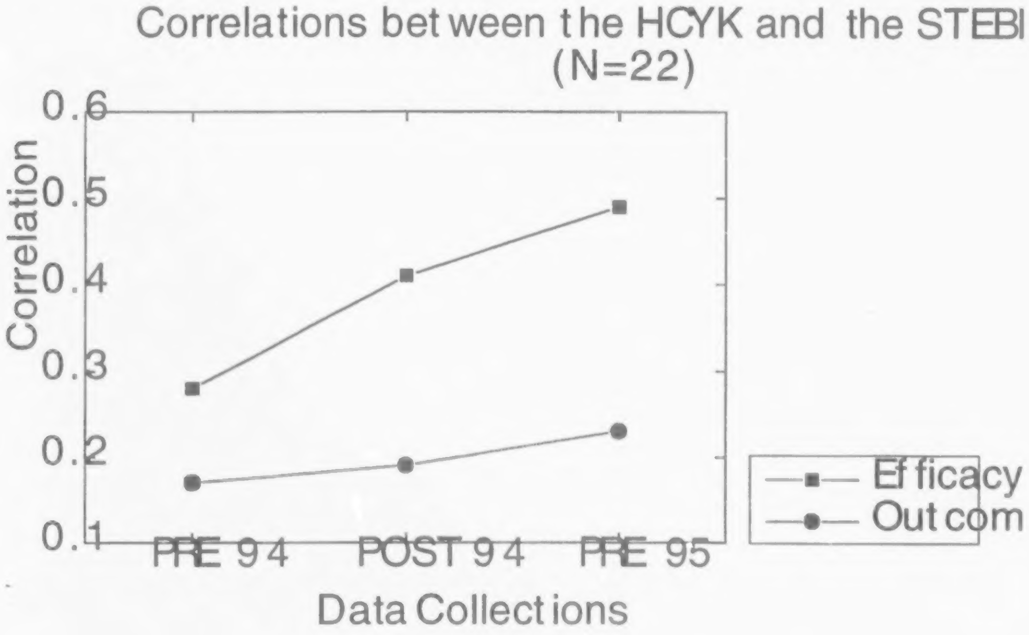


Figure 6. The correlation between the teacher knowledge of the How Can You Know and the teacher efficacy beliefs.

The How Can You Know and the Stages of Concern

Overall, the correlations between the HCYK and the subscales of the Stages of Concern tend to decrease and thus move toward negative correlation except "Awareness" subscale. This seems to mean that those who had more confident knowledge of the How Can You Know hold lower level of concerns about this innovation. Especially, the teachers' level of concern about the informational aspect presented a significantly negative correlation of -0.69 at the post-test of the 1994. Several subcomponents of the Stage of Concern instrument, such as management, refocusing, consequential, and personal concerns, also tends to present negative correlations at the end of 1994 workshop, but did not show a significant level of relationships.

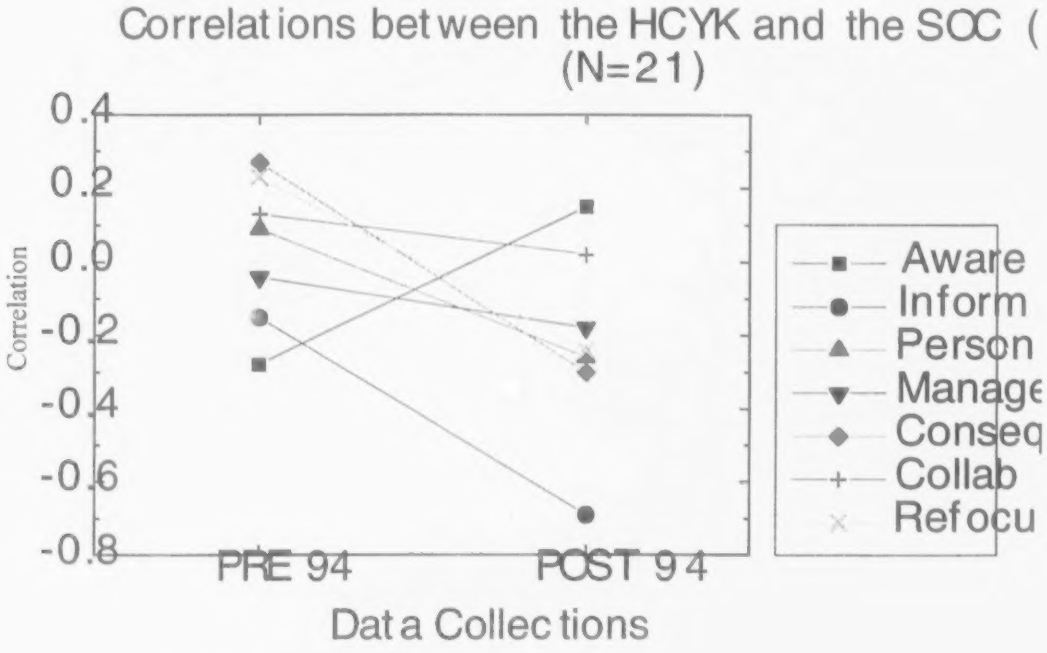


Figure 7. The correlation between teacher knowledge of the How Can You Know and the Stages of Concern.

Summary of Findings

Those findings from data analysis are summarized as follows.

1. This data analysis suggests that teacher beliefs about the nature of science are not easily changed, and initial level of teacher knowledge can affect the amount of changes in teacher beliefs. The subscale which show the highest mean score throughout the tests presents minimal increases in the score during the workshop. Two subscales called "Creative" and "Unified" provide the largest amount of changes with regard to the mean scores between initial and final tests.

2. Throughout the five data collections over three years summer workshops, the scores of self efficacy and outcome expectancy shows increased and parallel trend with regard to each other. In each subscale variable, the participants show a gain during the course of the first workshop. But when the teachers returned for the second year workshop, the scores were decreased. This is regarded as a common pattern after working with children at school after the workshop.

3. By the end of the first year workshop, many participants showed that they not only had knowledge of how we know with regard to the most of items of the "How Can You Know" instrument, but also indicated a willingness to teach these concepts. A continuous data collection had not been done, but the data analysis results provide the evidences of the teachers' knowledge growth about how we know during the workshop.

4. Three components of concern, informational, personal, and collaboration, were rated high at the initial data collection. The highest concern was about the availability of information to help teaching about the nature of science. At the end of the three year summer workshops, informational and personal concerns were diminished from the percentile scores of 88.9 and 82.0 to the values of 63.4 and 50.9 respectively. However, the concern of collaboration persisted throughout the whole workshop and the value was increased to 90.2 at the end of the 1996 workshop.

5. The data analysis result didn't provide patterns of change in the relationship between teacher efficacy beliefs and knowledge of the nature of science during workshops. However, two subscales of the NOS instrument labeled "Testable" and "Unified" had positive correlations with the two subscales of STEBI instrument, self efficacy and outcome expectancy. Those positive correlation values show that the participants who have high mean scores of the NOS tends to have high self efficacy beliefs.

6. The frequency distribution tables also provided a positive relationship between teacher knowledge of the nature of science (Testable and Creative) and the STEBI especially among the low and high scored group categorized by the scores of the HCYK. This result looks consistent with the correlation coefficient analysis result.

7. The correlation between the HCYK and the "Self Efficacy" scale of the STEBI instrument indicated positive correlation ranged from 0.28 at the pretest of 1994 to 0.49 at the pretest of 1995. Because the HCYK data were only collected the first three times, it is difficult to conclude that the relationship between teacher efficacy beliefs and knowledge of the How Can You Know tends to grow during the workshops. It can only tentatively suggest that as teachers feel more comfortable to use their knowledge of how we know, teachers became more confident about their teaching with the benefit of participating in the workshops.

Conclusions and Implications

In answering research question one, it was found that most of the teachers in this study showed gains of knowledge about science and science teaching with regard to several measurements scores, which include the nature of science, teacher efficacy beliefs, stages of concern, and how can you know. Yet, it hardly provides exact patterns of change in teacher knowledge and beliefs during the workshops. Though we cannot generalize because of the gaps in the data collection, there was a common pattern, which shows when the teachers returned for the second year workshop after working at school, most of the pretest scores at the second year workshop were decreased from the previous workshop.

In answering research question two, there was found a growing positive relationship between the teachers' knowledge about the nature of science and teacher efficacy beliefs as the workshop went on. At the beginning of the first year workshop, the teachers' efficacy beliefs were not related to their level of knowledge about the nature of science. Yet, not all the subscales of the nature of science have a consistent result. It may suggest that certain aspects of the nature of science such as "testable" subscale, seems to be more closely related to teacher efficacy beliefs than the other aspects like "creative" subscale. According to the data analysis result, the creative aspect of the nature of science appears to be rather unstable and less reliable in the structure of teacher knowledge and beliefs than the other aspects of the nature of science. The relationship between the teacher knowledge of the creative nature of science and the teacher self-efficacy even tends to fluctuate during the sequence of the workshops.

Data analysis results may present the patterns of change which describe the increasing level of interrelationship between two different constructs, yet, it should not be overgeneralized. However, it can be noticed that there was a tendency toward an increasingly positive relationship between teacher knowledge of science and teacher efficacy beliefs in many subscales of the nature of science instrument.

From the conclusions, several suggestions for the future study were emerged. First, we need to be able to more clearly define the nature of science that are included in school science education. Second, it is important to provide time and opportunity to make teacher explicitly aware of their own knowledge and beliefs of the nature of science, so that we can facilitate congruent growth in the different aspects of teacher knowledge and beliefs. Third, it is not easy to identify the level of teacher knowledge and beliefs not only because of those tacit and implicit characteristics of those constructs but also because of the limitations of using less valid instruments. The importance of this methodological consideration was suggested. Fourth, in order to draw more confident empirical evidences, longitudinal study is recommended in a on-going and consistent way in large scale.

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INVESTIGATING PRESERVICE ELEMENTARY TEACHERS' SELF-EFFICACY RELATIVE TO SELF IMAGE AS A SCIENCE TEACHER

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One concern of science educators is the attitude of preservice science teachers toward science teaching. Consequently, the goal of developing positive attitudes in preservice teachers emerges frequently in science education courses and programs. Studies have indicated that, particularly at the elementary school level, negative attitudes and low comfort levels toward science and/or science teaching tend to lead to the sporadic teaching of science, the teaching of science during inadequate blocks of time, or the omission of science instruction from the school day (Finson & Beaver, 1994; Riggs & Enochs, 1990; Wilson & Scharmann, 1994; Koballa & Crawley, 1985).

At least some aspects of attitude appear to be related to self-efficacy. In science teaching contexts, self-efficacy is an individual's belief that one has the ability to effectively perform science teaching behaviors (called personal science teaching efficacy) as well as one's belief that his/her students can learn science given factors external to the teacher (called science teaching outcome expectancy), such as gender, ethnicity, etc. (Ramey-Gassert, Shroyer & Staver, 1996). When teachers have a low self-efficacy, their teaching tends to be characterized by authoritative, teacher-centered roles with a less clear understanding of the various developmental levels of their students. Rubeck and Enochs (1991) reported teachers who were weak in content background tended to have significantly lower personal efficacy than did teachers with strong content backgrounds. In contrast, teachers with a high self-efficacy tend to teach in ways characterized by the use of inquiry approaches, more student-centered thought, beliefs that they can help any student overcome learning problems and succeed, and are more knowledgeable of their students' developmental levels. One logical conclusion is that the way preservice teachers view themselves and their roles in a science teaching context is at least partially derived from their self-efficacy.

The attitudes students posses with respect to science may also be related to the ways they perceive themselves in the role of being a scientist. Yager and Yager (1985), for example, found that if the work in which scientists engage is viewed as being unpleasant, then one's perception of a scientist (or the prospect of becoming a scientist) becomes more negative. Investigations into the perceptions of scientists have occurred for decades, with a notable early study being Mead and Metraux's work in 1957. Their work led later researchers to examine elements of students' perceptions which could be classified as stereotypical (Chambers, 1983; Schibeci & Sorensen, 1993; Ward, 1977). The elements of one's perceptions about scientists are revealed through drawings one makes of a scientist. These stereotypical elements were refined by Chambers (1983) in his Draw-A-Scientist Test and later organized into a quantifiable checklist (the DAST-C) format by Finson, Beaver and Cramond (1995).

Thomas and Pedersen (1998) reasoned that since students' drawings reveal much about their perceptions of scientists, drawings might also reveal students' perceptions about themselves as science teachers. In their work, Thomas and Pedersen began with the DAST-C and revised it to include elements they judged to be characteristic of science classrooms and science teachers, calling the instrument the Draw A Science Teacher Teaching Checklist (DASTT-C). Through a collaborative effort with over a dozen science educators, the DASTT-C was further revised and refined over the duration of nearly two years.

In 1998, Finson, Riggs and Jesunathadas reported on a preliminary effort to compare preservice teachers' DASTT-C scores with those from the STEBI-B. For purposes of their study, these researchers identified four variables from the DASTT-C to compare with STEBI scores: teacher demonstrating/handling/manipulating objects, students conducting hands-on activity, environment inside, and environment including symbols of science. Procedurally, only pretest data from three different elementary science methods sections were compared. Results indicated preservice teachers with high self-efficacies were more inclined to include drawings showing outdoor environments used for teaching, students engaged in group work doing hands-on activities, and captions which added description and detail to the drawing. In contrast, low self-efficacy preservice teachers' drawings tended to exclude students, be centered indoors, had relatively few if any captions, and showed the teacher as the central figure. These results supported the underpinning STEBI theory's notion that those with higher self-efficacy believe in their own ability to teach, and are willing to add explanations focusing on the steps of their pictured lessons. These results further supported the theory's premise that individuals having high self-efficacy are more likely to utilize teaching strategies allowing students more variability in their classroom behavior. This led to the study hypothesis that preservice teachers who become less stereotypical in their perceptions of their science teaching will also develop higher levels of self-efficacy.

Procedures

Instruments

DASTT-C

The DASTT-C (Draw a Science Teacher Teaching Checklist) consists of three sections: Teacher, Students, and Environment. The "Teacher" section of the instrument is divided into two subsections which focus on the teacher's activity (demonstrating, lecturing, using visual aids, etc.) and the teacher's position (location with respect to students, such as at the head of the classroom; and posture). The "Students" section of the instrument is likewise divided into two subsections which focus on the activities of students (passively receiving information, responding to the teacher, etc.) and students' positions (seated within the classroom). The third section, "Environment," consists of elements typically found inside classrooms, such as desks arranged in rows, symbols of teaching (e.g. chalkboards) and of science (e.g. science equipment), etc. Each element in each section of the instrument is considered by the instrument's developers to depict stereotypical elements of teaching and classroom images. If a stereotypical element appears in a subject's drawing, the scorer can simply mark that element on the checklist in the space provided next to that particular element. Marks can later be added to derive both subscores for each section as well as an overall checklist score. Total checklist scores can range from 0 to 14. The "Teacher" subscore can range from 0 to 6, the "Students" subscore can range from 0 to 3, and the "Environment" subscore can range from 0 to 5. In each case, the higher the score, the more stereotypical the image being examined.

Accompanying the checklist itself is the subject response sheet. This sheet provides blanks at the top for subjects to enter demographic information [gender, preservice or inservice, grade level (elementary, middle/jr. high, high school), identification number, and date. In the center of the sheet is a square in which subjects are asked to make their drawing. Beneath the square is the drawing prompt, "Draw a picture of yourself as a science teacher at work."

STEBI-B

The STEBI-B consists of 23 statements which are divided to provide two subscores. Subscore statements are randomly embedded within the 23 statements of the instrument. Thirteen of the statements yield scores for the Personal Science Teaching Efficacy(PSTE) subscale while ten yield scores for the Outcome Expectancy (OE) subscale. All 23 statements have a five-point Likert-type scale. Respondents select one answer for each statement according to whether they strongly agree (5), agree (4), are uncertain (3), disagree (2), or strongly disagree (1). Any positively worded statement is scored by awarding five points for "strongly agree" responses, four points for "agree" responses, and so forth. Negatively worded statements are scored by reversing the numeric values. The range of PSTE scores possible is 13-65 while that of OE scores is 10-50. The instrument's developers established reliability coefficients of 0.90 and 0.79 for the PSTE and OE subscales respectively. Adding the two subscores together to derive an overall STEBI score is an inappropriate use of the instrument. Factor analysis was used to determine instrument validity.

Subjects

The subjects for this study were twenty seven elementary education majors attending a rural mid-sized midwestern regional four-year university. All were enrolled in an elementary science methods course during the spring semester of the academic year. The students comprising the course section were juniors, and twenty of them were female.

Data Collection

Both the DASTT-C and STEBI-B were administered to the preservice teachers during the first meeting of the course in January as pretests, and were again administered on the final day of the semester as posttests. The same instructor administered both pretests and posttests, as well as instructing the course. For each test administration, the only direction provided by the instructor was, "Draw a picture of yourself as a science teacher at work" and "When finished with your drawing, turn it over and write a description of yourself as a science teacher at work." Preservice teachers were provided the DASTT-C drawing page (a page with some demographic information listed at the top and with a square space in the center of the page for the drawing) and pencils if needed.

The science methods course in which the students (preservice teachers) enrolled was designed with a constructivist approach in mind. At the beginning of the course, students were provided a list of course topics for each day of the semester. Students were placed in cooperative groups and were instructed to research information regarding each daily topic. The intent was for students to seek information from their textbook, library resources, and the internet on the "topic of the day" in order to be prepared to present that information during the day on which that topic was discussed in class. Part of each class session was devoted to students sharing the information they had gathered, discussing it, and evaluating the information insofar as it pertained to teaching science to elementary children. As needed, the instructor would add information to the discussion, and would pose questions to students to guide them in their reflections and analyses of the information presented. Course topics included those typical of most science methods courses (e.g. science process skills, learning theory and theorists, issues in science/science education, types of lesson planning and delivery modes, constructivism, types of inquiry, etc.).

Another part of the class session would be spent in hands-on activities relating to the topic, and which were designed to illustrate a variety of lesson types, including open-ended, closed-ended, verification, and inquiry-based activities. The activities were then examined with respect to how they related to the topic information previously discussed and as to how they could be applied to elementary children at different grade levels. When appropriate, safety and technological issues were addressed. Another aspect of the course was project-based, in which students began by selecting a topic on which they individually could do an inquiry investigation. This model has been suggested by a number of researchers in recent literature (Crawford, 1999). Each student was required to complete his/her inquiry investigation and then write a technical report following a prescribed format. The project was later used as a basis for students developing classroom lessons targeting specified grade levels, which were in turn used as a basis for the development of both traditional and performance assessments. During the semester, students were also afforded opportunities through other courses to observe elementary classrooms in the field, and to begin preparing and delivering lessons to children.

For data analysis, all drawings were scored using the DASTT-C checklist, as were all written narratives. Dependent t-tests were performed on pre-post DASTT-C drawing data, DASTT-C narrative data, and STEBI-B data (for both OE and PSTE subscales). Pearson correlations were then calculated for comparisons between DASTT-C and STEBI-B scores. For comparative purposes in the correlations, student scores on the OE and PSTE subscales were categorized as either "high" or "low" for both pretests and posttests. "High" OE scores were scores equal to or exceeding one standard deviation above the mean, while "low" OE scores were scores equal to or less than one standard deviation below the mean. PSTE scores were similarly categorized into "high" and "low" groupings. These procedures were followed since previous studies indicate subjects having low PSTE scores tend to teach, or view their teaching, to be more expository while those having high PSTE scores tend to use more exploratory strategies. Additionally, low PSTE scoring subjects tend to see themselves as control figures who teach indoors and whose drawings tend to lack students. Conversely, subjects who have high PSTE scores are more likely to include images of teaching outdoors, to use hands-on activities, and to utilize group work strategies. The study hypotheses also suggested that subjects

having low DASTT-C scores would view themselves and their teaching as less stereotypical and should tend toward higher PSTE scores on the
STEBI-B.

Results

Dependent t-tests were conducted on pretest-posttest data for DASTT-C drawings. Analysis was performed on total checklist scores as well as for each subsection of the checklist. As shown in Table 1, means for total checklist scores decreased from pretesting to posttesting. There were similar decreases in means from pretesting to posttesting for the "Teacher" and "Environment" subsections. The "Student" subsection means showed in increase by posttesting. Only the mean change for the "Teacher" subsection was significant ($p < 0.001$).

Scores on written narratives were also analyzed using dependent t-tests. As with the drawing scores, analysis was conducted on the total score as well as on subsection scores of the DASTT-C checklist. Table 2 shows that mean changes from pretest to posttest decreased for the total score as well as for each subsection. Significant changes were found for mean changes in the total score ($p < 0.006$), the "Teacher" subsection ($p < 0.0001$), and the "Students" subsection ($p< 0.009$).

Identical procedures were used for STEBI-B data. As shown in Table 3, the means for the OE subscale increased significantly ($p <$ p.008) from pretesting to posttesting, and the means for the PSTE subscale increased significantly ($p < 0.0001$) by posttesting. Since it is inappropriate to add OE and PSTE scores together to derive a "total" STEBI score, no analysis was performed on total STEBI mean changes.

Pearson correlations were conducted on data to compare high and low PSTE and OE scores for both drawings and written narratives with STEBI-B scores. Results are shown in Table 4. Correlations ranged from none and slight (e.g., high OE and "Students" subscale from drawing samples) to very high (e.g., high OE and "Environment" subscale from drawing samples). Most negative correlations occurred for high OE and high PSTE scores. The reader should keep in mind that, hypothetically, increasing STEBI-B scores and decreasing DASTT-C scores should indicate similar types of self-perceptions in subjects, and therefore negative correlations should be anticipated as subjects grow to believe in their ability to impact students through their science teaching (PSTE) and move away from more traditional/stereotypical methodologies (DASTT-C).

Table 1

Means and Standard Deviations on DASTT-C Drawings (n = 27)

Checklist Section	Pretest	Pretest SD	Posttest	Posttest SD			
Teacher	3.444*	1.155	2.667*	1.144	0.815	0.786	1.074
	0.829						
Environment	1.889	1.450	1.593	1.309			
Total	6.148	2.445	5.333	2.732			

* Dependent t-test: $t = 3.721$, $p < 0.001$

Table 2

Means and Standard Deviations on DASTT-C Narratives (n = 27)

Checklist Section	Pretest	Pretest SD	Posttest	Posttest SD
Teacher	1.000*	0.620	0.444*	0.506
Student	0.630**	0.492	0.333**	0.480
Environment	0.444	0.577	0.407	0.501
Total	2.074***	1.385	1.185***	1.111

* Dependent t-test: $t = 4.130$, $p < 0.0001$
** Dependent t-test: $t = 2.842$, $p < 0.009$
*** Dependent t-test: $t = 3.024$, $p < 0.006$

Table 3

Means and Standard Deviations on STEBI (n = 27)

Subscale	Pretest	Pretest SD	Posttest	Posttest SD
OE	39.074*	4.402	41.667*	4.969
PSTE	42.111**	5.740	49.037**	6.454

* Dependent t-test: $t = 2.896, p < 0.008$
** Dependent t-test: $t = 6.901, p < 0.0001$

Discussion

Preservice Teachers' Drawings

The drawings made by the preservice teachers became less stereotypical from pretesting to posttesting with a mean change of 0.815 (See Table 1). If preservice teachers' perceptions become less stereotypical with appropriate methods course instruction, one should expect such a change. In terms of the subcategories of the "teacher," "students," and "environment," one might further expect each of these subscores to become lower (less stereotypical) between pretesting and posttesting as well. The results shown in Table 1 indicate this was the case for "teacher" and "environment" but not for "students." The "teacher" subscore changes were significant ($p < 0.001$). The "students" subscore mean increased from pretesting to posttesting. One might

Table 4
Correlations Between STEBI PSTE and DASTT-C Scores

			DASTT-C Subscales Scores			
	"Teacher" "Environment"		"Students" "Total" Score			
STEBI Subscale Score	Drawing Narrative	Narrative Drawing	Drawing Narrative	Narrative	Drawing	
Pretest						
"High" OE*	-	-1.000	0.870	-1.000	-0.927	-0.577
"Low" OE**	1.000	0.408	0.408	-0.408	0.943	0.612
"High" PSTE	-0.503	-0.917	-0.494	-0.367	-0.308	0.071
"Low" PSTE	0.557	-	0.651	-0.156	0.752	-0.662
Posttest						
"High" OE	0.779	0.559	-0.127	0.592	0.775	0.395
"Low" OE	1.000	-	1.000	-	-	1.000
"High" PSTE	0.052	-0.277	0.971	0.693	0.693	0.000
"Low" PSTE	0.434	-0.270	0.000	-0.270	-0.772	0.836

* n = 4
** n = 5
n = 4
n = 7
n = 5
n = 2
n = 3
n = 5

conjecture that as preservice teachers became more aware of the teaching process, the prevalence of "students" in their mental images would increase. Coupled with the preservice teachers' exposure to a single semester of methods classes and little exposure to students in actual classrooms, one might further anticipate that preservice teachers' images of students might tend toward the more stereotypical. This could explain the results reported here.

Preservice Teachers' Narratives

The narratives written by the preservice teachers became less stereotypical from pretesting to posttesting (see Table 2), and these changes were significant ($p < 0.0001$ for the "teacher" subscore and $p < 0.009$ for the "students" subscore). This change was exhibited for each of the subscales of "teacher,""students," and "environment." One might expect preservice teachers' narratives to include more detail and information about their perceptions of themselves teaching science than would emerge from their drawings. For this group of subjects, however, this was not the case. Narrative scores for each subscale, as well as for the total score, were significantly lower than drawing scores for both the pretest (total score $p < 0.0001$) and posttest (total score $p < 0.0001$). This may have been an artifact of perceived lack of time to formulate ideas, compose them, and write them down. Even so, the overall trend of the change in narrative scores from pretest to posttest paralleled that for drawing scores. Little clarifying information was gleaned from the narratives which could be used to enhance the drawings.

Preservice Teachers' Self-Efficacy

In terms of self-efficacy, one would hope to see preservice teachers' OE and PSTE scores to increase between pretesting and posttesting. An examination of Table 3 reveals this was the case. The change in OE subscore means was significant ($p < 0.008$) as was that for PSTE subscore means ($p < 0.0001$). Of particular interest are the PSTE subscores derived from the STEBI. High PSTE scores tend to reflect feelings of one's ability to impact student learning, and are usually matched with teachers who employ more exploratory teaching methodologies, who see themselves teaching students in nontraditional ways such as group work and hands-on work, and not always in the traditional classroom setting. In comparison, low PSTE scores tend to reflect feelings of one's inability to impact student learning, and are matched with more didactic, expository teaching approaches, and teaching students in more traditional modalities. Students are seen more as being quiet absorbers of information who are arranged in rows facing the teacher within a controlled classroom setting.

Comparison of Drawing Scores With Self-Efficacy Scores

One might infer that a correlation would exist between someone's perception of themselves as a science teacher teaching science and their self-efficacy. This would logically lead to the inference that low PSTE scores would correlate with high stereotypical images revealed in both drawings and narratives of one's teaching, while high PSTE scores would correlate with lower stereotypical images. These inferences were examined by calculating correlations between PSTE and DASTT-C subscores.

According to this logic, one might hypothesize a preservice teacher having a low PSTE score should also have higher stereotypical scores for DASTT-C element subscores in "teacher," "students," and "environment." Conversely, a preservice teacher having a high PSTE score should also have lower stereotypical scores for the same DASTT-C element subscores, resulting in negative correlations for each DASTT-C element. To help in examining these possible relationships, preservice teachers' PSTE scores were designated as being "low" if they fell one standard deviation or lower than the PSTE mean, and were designated as "high" if they fell one standard deviation or higher than the PSTE mean. Using these criteria, correlations were made on both the pretest and posttest data.

Pretest correlations tended to support the hypothesis noted in the foregoing paragraph (see Table 4). Correlations between PSTE and DASTT-C "teacher" and "students" scores were moderate for both low and high PSTE scores, with those on the posttest being negative. Those on the "environment" element were high and positive for individuals who had low PSTE scores and were low and negative for those individuals having a high PSTE score. When examining PSTE scores and total DASTT-C scores, correlations were positive and high for those individuals having a low PSTE score and were moderate and negative for those having a high PSTE score.

When the same comparisons were made using posttest data, results were more mixed. Low PSTE scores tended to correlate moderately and positively with DASTT-C "teacher" scores, to have no correlation with "students" subscores, and to correlate high and negatively with "environment" scores. High PSTE scores had slight or negligible correlation with "teacher" scores, a very high and positive correlation with "students" scores, and a moderate and positive correlation with "environment" scores. These results are not what one would expect on the surface. However, one may hypothesize that preservice teachers having low PSTE scores might be almost entirely focused on themselves and therefore would not consider "students" in their image of science teaching. They may be sensitive to the environment in which they see themselves teaching, and would most likely see that environment as being in a very traditional (stereotypical) classroom setting. If true, this might account for the types of correlations derived in this study. For preservice teachers having high PSTE scores, their focus may similarly shift somewhat to the environment, thus accounting for the positive correlation between PSTE and DASTT-C "environment" scores. Their focus may now also include more about students, so DASTT-C "students" elements may begin to emerge more regularly. This may account for the moderate and positive correlation between PSTE and DASTT-C "students" scores.

Similar comparisons were made between PSTE scores and DASTT-C narrative scores. Pretest correlations of scores from low PSTE preservice teachers tended to be negative and ranged from very high for "teaching" to low for "students" to very slight for "environment." Correlations of scores from high PSTE preservice teachers were slight and negative for both "teacher" and "students" DASTT-C elements yet were high and positive for the "environment" element. The negative correlations might be attributable simply to subjects simply not writing much in their respective narratives which could be scored using the DASTT-C. The positive high correlation for high PSTE subjects and their "environment" scores are more problematic to explain.

Conclusions

The study hypothesis was that preservice teachers who become less stereotypical in their perceptions of their science teaching will also develop higher levels of self-efficacy. In general, the results of this study would appear to support the hypothesis. However, acceptance of the hypothesis needs to be tempered with regard to several factors as discussed below.

With regard to only using DASTT-C data, one should be able to use the instrument and gain some sense of the perceptions preservice teachers have of themselves teaching science. Of all three subscales in the instrument, the one proving to be most problematic is that for "students," since preservice teachers may tend to focus primarily on themselves and have not yet matured into merging their self image with the image of being amongst students. The useful contribution of narrative data provided by preservice teachers is somewhat questionable, at least with respect to how it was collected for this study. Preservice teachers were requested to write their narratives on the reverse side of their drawings during the same session during which they made their drawings. Perhaps having them write a separate paper to later be matched to their drawings would provide more usable detail. The original intent of having subjects write about the drawings they just made and then using the narrative to augment the drawing for scoring purposes may need to be revisited. One may suggest providing subjects with a more thorough prompt to use in addressing their narrative information, but this may alter their original perceptions preservice teachers have of themselves teaching science as revealed in their drawings, causing them to modify their drawings before submitting them.

Further use of the DASTT-C will be necessary for other groups, such as for secondary science preservice teachers. Science educators may find it interesting to compare the self images, as defined by the DASTT-C, between elementary and secondary preservice teachers. Similarly, application of the DASTT-C between various cultural groups may be of interest, as might be its application to groups of different geographic locality (eg. region of the U.S., other nations, urban or rural, etc.).

Additional difficulties may arise when attempting to compare DASTT-C scores with STEBI scores, particularly for the PSTE subscale. There is more refinement needing to be done in how to interpret DASTT-C scores and whether it is appropriate to (and if so, how to) compare them with scores from other instruments such as the STEBI. By themselves, both instruments provide valuable insights into the way preservice teachers see themselves with regard to science teaching. Any relationships between self image and self-efficacy, although intuitively related, may be difficult to elicit from these particular instruments. Whether one can be used efficiently and effectively in conjunction with the other will require further work. Perhaps each instrument provides a slightly different picture of preservice teachers' perceptions, slightly different pieces of the entire self image. Use of the two instruments together may be of benefit to science educators, even though the relationship between the two is not clearly defined. The same may be said for other instruments in existence as well.

Finally, the results of this pilot test of the DASTT-C and its comparison with STEBI scores must be viewed with caution for several reasons. First, the size of the comparative groups was small. In one instance, the "high" PSTE group had an n of only 3 and that for the low group was 5. The size of the entire section of the methods course was 27. This study should be repeated with larger numbers of preservice teachers before firmer conclusions can be drawn from it. Second, the DASTT-C itself may yet require some additional modification. Although the instrument has undergone numerous iterations over its development and refinement throughout the three years of its existence, there may be need for additional, minor modifications. Even minor modifications might result in different scores being derived through use of the instrument. Third, for various reasons alluded to previously, direct comparisons between an instrument like the DASTT-C and other instruments like the STEBI may not be appropriate, even though they each look at similar types of things. Considering these cautions, this pilot study appears to indicate the DASTT-C can be used effectively with preservice teachers to begin discerning their perceptions of themselves as teachers teaching science. This study further indicates that there may be some underlying relationship between such self-perceptions (as measured by the DASTT-C) and the self-efficacy an individual possesses with regard to science teaching.

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DEVELOPMENT OF A SELF-EFFICACY BELIEFS ABOUT EQUITABLE SCIENCE TEACHING AND LEARNING INSTRUMENT FOR PROSPECTIVE ELEMENTARY TEACHERS

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While the 1997 TIMSS data for grade four suggests that we are moving toward being "first in the world in mathematics and science achievement by the year 2000," these data do not indicate whether all groups of elementary students performed equally well. By contrast, the most recent National Assessment of Educational Progress (NAEP, 1996) results for 9-year-olds (fourth grade) show differences in science proficiency by race, ethnicity and gender. NAEP found that for the 9 year-old group, males out performed females, and White, non -Hispanic children scored higher then Black and non-Hispanic children with Hispanic children scoring the lowest. The NAEP results also show that 13 year-old males did better then females, that White non-Hispanic children scored higher than Hispanic children and that Black children scored the lowest.

Studies have shown gender inequity with higher academic achievement for boys than girls, classroom interactions between teacher and students that favor boys, sexual stereotyping, and gender bias in curricular materials. (AAUW, 1992; Kahle & Meese, 1994; Kelly, 1985; Tobin, K., & Garnett, P. 1987) Several studies have documented that teachers interact with male students more then females (American Association of University Women, 1992, Brophy & Good, 1970; Datta, Schaefer, & Davis, 1968; Dweck & Bush, 1976; Martin, 1972; Sadker & Sadker, 1985), especially White males (Irvine, 1990; Sadker & Sadker, 1981). Jackson and Cosca (1974) and Sadker and Sadker (1981) found that teachers interact with, call on with greater frequency, praise more highly, and intellectually challenge students who are middle class, male, and White.

Additionally, teachers have been found to lack knowledge about the history, ethnicity and culture of their children (Pearson, 1986). Allen and Seumptewa (1988) found that many of the non-Native American teachers who teach Native American students are in a quandary with the differences in the way that the children learn. These teachers often leave the reservation because they do not feel that they connect with the students. Stegemiller (1989) concluded from an analysis of 31 studies that teacher expectations for students are based on four factors: social class, attractiveness, ethnicity and perhaps gender. Thus, a white boy who comes from a middle or high socioeconomic class and is academically average to above average, has multiple advantages with the teacher over a minority girl or a student who comes from a low socioeconomic home or is academically challenged.

The inequality in interaction between teachers and students who are from low socioeconomic homes, ethnically and culturally diverse, and girls is compounded by the curriculum of science, which has been neglected in the elementary classroom (Tilgner, 1990; Westerback, 1982). This neglect is evident in the limited time teachers spend on teaching science, teachers lack of confidence in their ability to understand science content and to be able to teach that content effectively and their negative attitude toward the science curriculum.

The teachers' attitudes and interactions are critical elements in the success of all students. Elementary teachers have been known to have negative attitudes toward science (Shrigley, 1974), do not care for science (Tilgner, 1990), and do not have confidence in their ability to teach science (DeTure, Gregory, & Ramsey, 1990; Sunal, 1980 as cited in Park, 1996). This in turn causes elementary teachers to avoid teaching science to children (Czerniak & Chiarelott, 1990; Westerback, 1982, 1984) or spend less time teaching science as compared to other subjects (Good & Tom, 1985; Weiss, 1987; Westerback, 1984). Czerniak & Chiarelott, (1990) found that the negative attitudes of teachers can be correlated to students negative attitudes about science. An attitude according to Enochs and Riggs (1990) "is a general positive or negative feeling toward something" (p. 625). A belief as defined by Koballa and Crawley (1985) is "information that a person accepts to be true" (p.223). Both, however, influence behavior. Thus, teachers' attitudes, beliefs and interaction are critical elements in the success of scientific literacy for all students.

Currently, 25 of the 50 largest school districts in the United States have children of color as the majority student population (Banks, 1991). In states such as New Mexico, Texas and California children of color comprise 70 percent of the total student population (Quality Education for Minorities Project, 1990). Children of color make up 30 percent of the students in the country overall and the growth rate of the minority population segment is expected to increase to 40 percent by the year 2020 (Pallas, Natriell, & McDill, 1989). By contrast, when the demographics of the prospective elementary teacher population is examined, it is found to be predominately white, middle class and female (Banks, 1991). The elementary teacher population continues to be Caucasian, monolingual, and female with backgrounds different from those they will teach, while the face of the school population in the United States is becoming more diverse (American Association of Colleges of Teacher Education, 1987; Banks, 1991; Ducharmen and Agne, 1989; Haberman, 1987; Hodgknison, 1985).

Science for All Americans (1989) recognizes these inequalities and proposes that scientific literacy needs to be a goal of school science education for all young people, "those who in the past who have largely been bypassed in science and mathematics education: ethnic and language minorities and girls" (p. xviii). Questions concerning how scientific literacy can be achieved given inequality in interaction due to race, class and gender differences and teacher attitudes concerning the science curriculum are vital.

To ensure scientific literacy for all, it is important for elementary teachers to understand student diversity and be able to teach science for a diverse student population. Part of the solution may be in understanding the behaviors of prospective elementary teachers. Teacher beliefs appear to be good predictors of behavior (Ashton & Webb, 1986a, 1986b; Bandura, 1986; Riggs, 1988; Riggs & Enochs, 1990). Teacher self-efficacy beliefs, in particular, have been found to be valid predictors of practicing and prospective elementary teachers' behavior regarding science teaching and learning (Ashton & Webb, 1986a, 1986b; Bandura, 1986; Riggs, 1988; Riggs & Enochs, 1990).

Purpose of the Study

The purpose of this study was to develop, validate and establish the reliability of an instrument to assess the self-efficacy beliefs of prospective elementary teachers with regards to science teaching and learning for diverse learners. This is an important area of self-efficacy beliefs assessment for which an instrument does not exist. The study built upon the work of Ashton and

Webb (1986a, 1986b) and Bandura (1977, 1986), and the instrument was modeled after the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs,1988) and the Science Teaching Efficacy Belief Instrument for Prospective Teachers (STEBI-B) (Enochs & Riggs, 1990). It was proposed to be titled Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST).

According to Bandura, (1986, 1997), the construct of self-efficacy beliefs consists of the two dimensions: personal self-efficacy and outcome expectancy. Personal self-efficacy "is a judgment of one's ability to organize and execute given types of performances, whereas an outcome expectation is a judgment of the likely consequence such performances will produce" (Bandura, 1997 p.21). An aim in developing the SEBEST was for each of the dimensions of self-efficacy beliefs of prospective elementary teachers toward teaching learning science for diverse learners, i.e., personal self-efficacy, outcome expectancy (Bandura, 1986), to be represented as a sub-scale.

Development of the SEBEST

A seven step plan was used to develop the SEBEST and build validity and high reliability into the instrument.

Step 1: Defining the Constructs and Content to be Measured

Diverse learners as recognized by *Science for All Americans* (1989) are "those who in the past have largely been bypassed in science and mathematics education: ethnic and language minorities and girls" (p. xviii). That definition was extended to include children from low socioeconomic backgrounds based on the research by Gomez and Tabachnick (1992). They found that the views of prospective teachers toward minority children and children from low-income families limit the children's opportunities to learn and prosper from schooling. Similarly, the work of Grant and Tate (1995) acknowledges "educational research becomes problematic when it does not include race, class, and gender, and/or when these constructs are not rigorously interrogated" (p. 147). For example, *The IEA study of Science II: Science Achievement in Twenty-three Countries*, found that family economic factors were related to achievement in science, the educational level of the parents, the size of the family, and the amount of reading material in the home (Postlethwaite & Wiley 1992). Baker (1998) proposes that "parental attitudes and economic condition of the family could be the major determinant of whether a girl will receive an education" (p. 879).

Figure 1 presents the Content Matrix that was developed for use in this study to define the content for the SEBEST. It is composed of the self-efficacy construct (i.e., personal self-efficacy and outcome expectancy dimensions), the definition of diverse learners developed for the study (i.e., ethnicity, language minorities, gender, and socioeconomic dimensions), and the phrasing dimensions for Likert items to be included in the SEBEST (i.e., positive and negative).

Step 2: Draft Item Preparation

Information on practices that are effective for teaching science to diverse student populations explicated in science education and multicultural education research, (for example, AAUW, 1992; Kahle & Meese, 1995; Kelly, 1985; Tobin, 1996, Atwater, 1994; Brickhouse, 1994; Gomez, 1996; Hodson, 1993; Rakow, 1985; Spurlin, 1995) informed the preparation of draft items for the SEBEST. One hundred ninety-five Likert type items, modeled after those composing the STEBI (Riggs, 1988) and STEBI-B (Enochs & Riggs, 1990) were drafted with at least six representatives for each cell in the Content Matrix presented in Figure 1.

Edward's (1957, pp. 13-14) fourteen guildelines for buidling item clarity also were used as a guide as draft items were written to reduce item error due to ambiguity. These guidelines include points, such as: (a) use items that refer to the present verses the past, (b) use simple, clear and direct language, (c) items should not use "all," "always," "none" or "never," (d) use care in using "only," "just" and "merely," and (e) avoid double negatives.

Step 3: Draft Item Review

A letter that explained the review task and the 195 draft items were submitted to 10 graduate students in Science Education at Penn State University. Edward's criteria and the definitions of self-efficacy beliefs, personal self-efficacy, outcome expectancy, ethnicity, language minorities and gender also were included. The graduate students independently reviewed each of the draft items for clarity and comprehension by prospective elementary teachers. Comments for valid subset of items. Coefficient Alpha, a measure of internal consistency, was used to examine the reliability of groups of items, item to total score correlation was used to determine the contribution of an item to total instrument score, and Chi Square was used to check item representation across the Content Matrix. Because the three qualities can be antithetical to one another – for example, the most construct valid and reliable set of items might not be representative of the Content Matrix -- these statistical techniques were applied multiple times and in combination to help select items for the SEBEST that gave the instrument the strongest profile across all three qualities.

The data used for these analyses were collected in step 5 by administering the 48 item "first draft" instrument to the 226 prospective elementary teachers in the Penn State University Elementary-Kindergarten Teacher Education (EK ED) program. Again, these included the students in the five sections of SCIED 458--Teaching Science in the Elementary School (n = 124) and in the nine sections of Elementary Student Teaching (n = 102) during the Fall semester of 1998. Usable data were secured from 217 of these prospective elementary teachers -- 120 of the students in SCIED 458 and 97 of the students in Elementary Student Teaching. The mean score on the 48 items among the 217 prospective elementary teachers was 151.45 with a standard deviation of 10.97 (scores on the 48 five-point Likert item instrument could range between 48 and 240).

Initial Factor Analysis Results

These data were subjected to Principal Component Factor Analysis using Varimax Rotation. The analysis generated 14 factors with an Eigenvalue of 1.00 or greater, that accounted for 64% of the variance in the instrument results. Because the desire was to select the smallest subset of the items that were construct valid, had high reliability and were representative of the Content Matrix, a Scree Plot was used to visually examine the number of factors and determine the number of significant factors. The Scree plot for the analysis is presented in Figure 2.

According to William and Goldstein (1984) the number of significant factors, or number of component factors to be retained, is visually indicated by the change in the slope of the plot --

improvement were recorded directly on the draft items.

The feedback was used in revising the draft items. The revised items were resubmitted to the graduate students and subsequently revised until all ten graduate students judged that clarity and comprehension was achieved for at least five items in each cell of the matrix. Eighty items were identified within two rounds of review.

Step 4: Revised Item Content Validity

A panel composed of eight faculty members from inside and outside of Penn State university representing science education, multicultural education, and self-efficacy research, was constituted for the purpose of judging the content validity of the 80 revised items. The panel members were given a letter of explanation, the revised items, the definitions of terms used within the instrument and Edwards criteria. They worked independently to judge the content of the items and their feedback was used to revise the items. The items were to be resubmitted to the faculty members until at least four items in each cell of the Content Matrix (Figure 1) were judged content valid by five of the judges. However, this proved unnecessary given that a sufficient number of the items, 48 with at least 6 items representing each cell in the Content Matrix, were judged content valid after one review. These 48 content valid items constituted the "first draft" of the instrument.

Step 5: First Draft Instrument Try Out

The "first draft" instrument was administered to the 124 prospective elementary teachers in the five sections of SCIED 458--Teaching Elementary School Science and the 102 prospective elementary teachers in the nine sections of Elementary Student Teaching at Penn State University during the second week of November 1999. These accessible groups represented the intended population for the final instrument. The resulting data were used in formulating the SEBEST as described in Step 6, below.

Step 6: SEBEST Formulation

The task in Step 6 of the development was three-fold: to identify a subset of the 48 items that : a) was construct valid, b) had high internal consistency reliability, and c) was representative of the Content Matrix presented in Figure 1. Factor analysis was used to help identify a construct

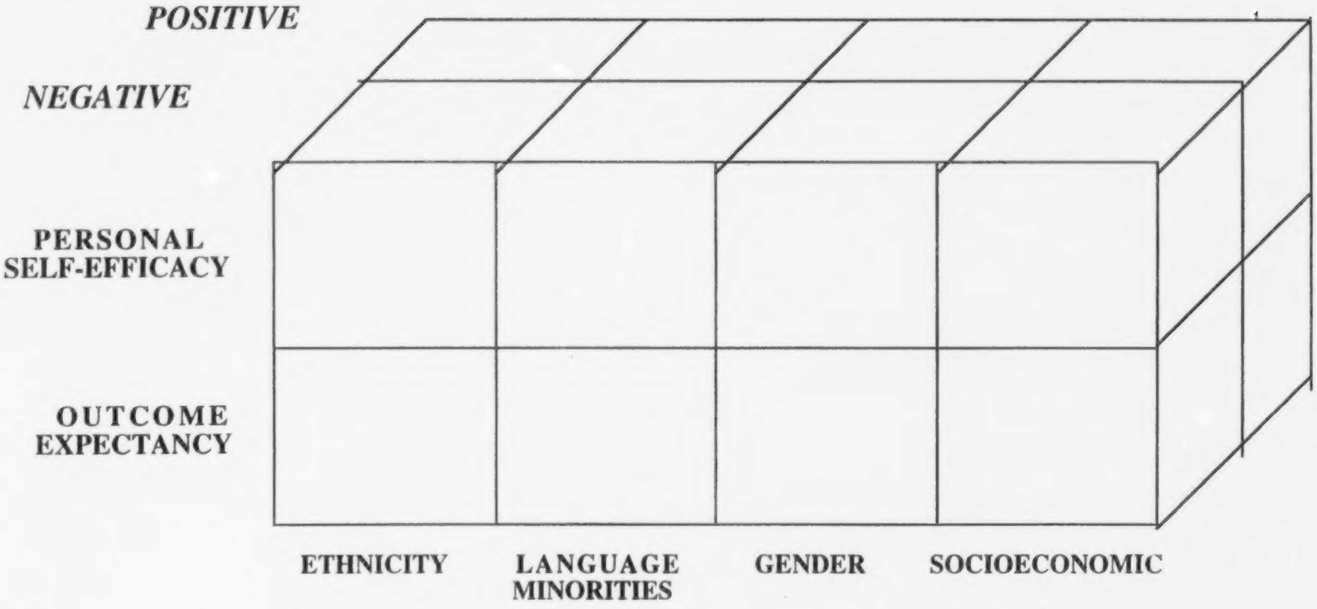
POSITIVE
NEGATIVE
PERSONAL SELF-EFFICACY
OUTCOME EXPECTANCY
ETHNICITY
LANGUAGE MINORITIES
GENDER
SOCIOECONOMIC

Figure 1. Content Matrix for the Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST).

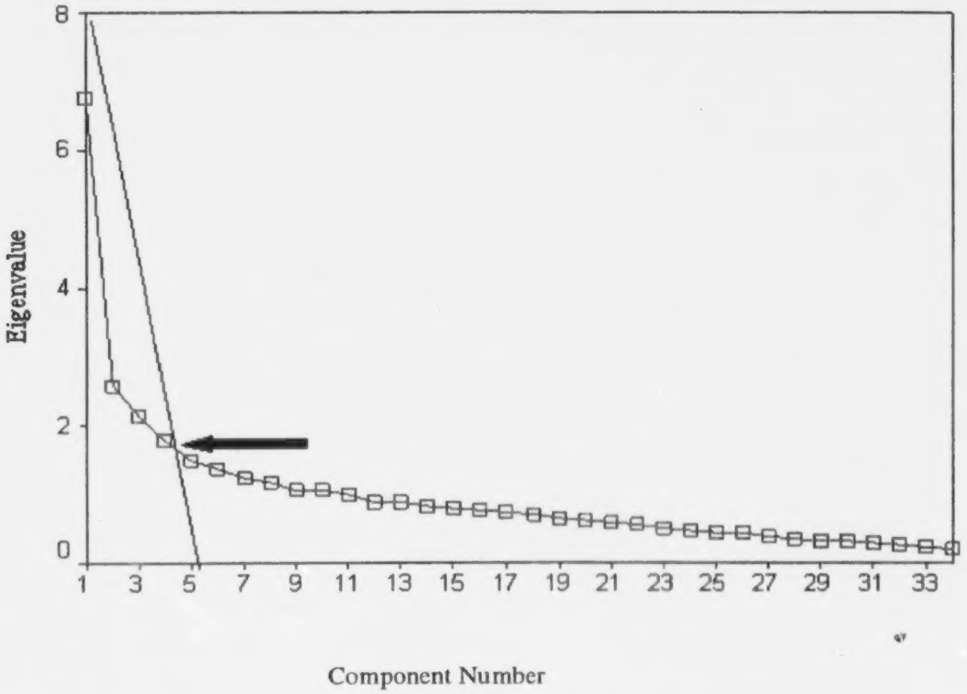

Figure 2. Scree Plot for 34 Items.

the point at which the Scree plot curve breaks and forms a relatively straight line by a series of smaller, non-significant, Eigenvalues. In Figure 2, the point at which the contour of the curve changes is marked with an arrow -- at an Eigenvalue of 1.7 and four components. Four factors were identified as significant using this method. Twenty-eight items loaded on these four factors. From a factor analysis perspective alone, the instrument might include 28 items.

Second Factor Analysis Results

The contribution each of the 48 items made to total instrument scores and reliability also was examined to determine the possible composition of the instrument from a reliability perspective. Thirty-four items were judged to be appropriate for inclusion in the instrument based on this perspective. That is, the 34 items that had the highest item to total instrument score correlations generated the highest Coefficient Alpha reliability for the total instrument and two sub-scales, i.e., personal self-efficacy, outcome expectency.

The 34 items were subjected to Principal Component Factor Analysis using Varimax Rotation. These items loaded across four factors, which accounted for 39.2% of the variance in the data. Table1 shows the item loading across the 14 factors, the variance accounted for by each factor and cumulatively across them, and the Content Matrix category for each item. As is noted, Factor 1 accounted for 11.6% of the variance in the instrument results, Factor 2 for 9.5%, Factor 3 for 9.3%, and Factor 4 for 8.9%. These percentages showed balanced variance across the four factors.

Additionally, the item factor loadings for the four factors were pure, with each factor being associated with either the Personal Self-Efficacy (PSE) or Outcome Expectancy (OE) dimension of Self-Efficacy Perception. Eleven items loaded on Factor 1, all associated with Personal Self-Efficacy (PSE), particularly socioeconomic status, gender and ethnicity. Factor 1, therefore, was identified with PSE. Ten items, all of which were associated with Outcome Expectancy (OE) and with language minorities, socioeconomic status, gender and ethnicity, loaded on Factor 2. Six items identified with PSE loaded on Factor 3, all associated with language minorities. Eight items associated with OE, but from across the Content Matrix, loaded on Factor 4. The reliability of the PSE items that loaded on Factor 1 was .82 and on Factor 3 was .80. The reliability for the OE items that loaded on Factor 2 was .72 and on Factor 4 was .75.

Chi Square Results

Table 2 shows the distribution for the 34 items across the Content Matrix presented in Figure 1. A Chi-Square test was used to determine whether the 34 items were balanced across Personal Self-Efficacy/Outcome Expectancy and Ethnicity/Language Minority/Gender/ Socioeconomic Status for the PSE and OE dimensions of the Content Matrix. The resulting statistic, $X^2 = 2.71$, $df = 7$, was not significant at the .05 level of probability. This was interpreted as evidence that each of the two dimensions of the self-efficacy construct and each of

Table 1

Factor Analysis Results for 34 Items

Items	Factor 1	Factor 2	Factor 3	Factor 4	Matrix Cell*
1			0.71		PSE:LM
2	0.49				PSE:SES
3				0.47	OE:G
4		0.54		OE:E	
5	0.63				PSE:E
6			0.65		PSE:LM
7	0.56				PSE:G
8		0.64		OE:E	
9			0.76		PSE:LM
10	0.49				PSE:G
12				0.65	OE:E
14		0.50		OE:LM	
15		0.63		OE:G	
16		0.68		OE:E	
17			0.65		PSE:LM
18	0.30				PSE:G
19				0.61	OE:SES
21				0.64	OE:G
22	0.69				PSE:E
24	0.38				PSE:E
25		0.42			OE:G
26	0.67				PSE:SES
28		0.45			OE:SES
29	0.79				PSE:E
30				0.49	OE:G
31			0.60		PSE:LM
34	0.67				PSE:E
40		0.42		0.29	OE:SES
41		0.53			OE:LM
42				0.64	OE:E
43		0.36		0.55	OE:SES
44	0.38				PSE:G
45		0.72			PSE:LM
48				0.39	OE:LM
% of Variance	11.6	9.5	9.3	8.9	
% Cumulative Variance	11.6	21.1	30.3	39.2	

* PSE = Personal Self Efficacy; OE = Outcome Expectancy
E = Ethnicity; G = Gender; LM = Language Minority; SES = Socioeconomic Status;

Table 2

Distribution of the 34 Items Across the Content Matrix

Dimensions/ Items	Ethnicity	Language Minority	Gender	Socioeconomic
Personal Self Efficacy	#7,#19,#27 #29,#33	#1.#5,#9,#13 #21,#25	#11,#15,#23 #31	#3,#17
Outcome Expectancy	#4,#12,#16 #22,#32	#18,#30, #34	#2,#8,#20, #26,#28	#6,#10, #14,#24

the four diverse groups of learners were represented in the 34 item instrument to no significant difference.

The SEBEST Instrument

The task in Step 6 was to identify a subset of the tryout items that was construct valid, had high internal consistency reliability, and was representative of the Content Matrix. Thirty-four items achieved this goal – gave the instrument the strongest profile across all three qualities – and so were used to compose the Self-Efficacy Beliefs about Equitable Science Teaching or SEBEST instrument. The 34 item SEBEST is presented in Appendix A. The even items compose the Personal Self-Efficacy or PSE Sub-Scale, and the odd items compose the Outcome Expectancy Sub-Scale.

Coefficient Alpha Reliability Results

Coefficient Alpha was used to assess the reliability of the 34 item SEBEST and its sub-scales using data secured from the 217 prospective elementary teachers. The reliability of the entire instrument was found to be .87. The reliability was .83 for the 17 PSE items or sub-scale and .78 for the 17 OE items or sub-scale. A reliability of .87 indicates that 76% of a respondent's score is true score variance and 24% due to error. Similarly, a reliability of .83 indicates 69% true score while 31% is error, and a reliability of .78 indicates that 61% is true score and 39% is due to error.

According to standards presented by Helton, Workman and Matuszchk (1982), a reliability coefficient of .90 or higher is desired for classroom classification decisions, although this benchmark is rarely met. Remmers, Gage and Rummel (1965) support a reliability coefficient of .80 or higher for school use and .70 or higher for research instruments, especially if group performance is only an issue. Reliability coefficients above .90 are considered necessary to make individual decisions with instrument results; above .80 are considered for research; and above .70 for initial group decisions that will be tested through additional means. (Nunnally, 1970) The reliability coefficient of .87 on the 34 item SEBEST, and .83 and .78 on its sub-scales, were interpreted as being well within the acceptable reliability range for a research instrument.

Step 7: Further Study of Reliability

The internal consistency and test-retest reliability of the 34 item SEBEST were examined with data from two other samples of prospective elementary teachers (samples of convenience) during the Spring of 1999. One consisted of 23 prospective teachers enrolled in the Urban Early and Middle Childhood Education Program (URBED) at the Penn State University Delaware Campus, a teacher education program with an urban education focus. These prospective elementary teachers were at the mid-point of their student teaching experience in an urban elementary school. They had completed all of the required coursework for a B.S. degree and elementary teacher certification in Pennsylvania, including URBED 403--Using Science and Mathematics Knowledge and Assessment in Urban Settings along with an associated in-school (urban) clinical experience during the Fall semester of 1999. The other sample consisted of 102 prospective teachers enrolled in the Elementary-Kindergarten Teacher Education Program (EK ED) at the Penn State University, University Park Campus. These prospective elementary teacher were at the mid-point of completing SCIED 458--Teaching Science in the Elementary School, along with mathematics and social studies teaching and learning courses and an associated in-school clinical experience. The vast majority would be student teaching during the next semester (Fall 1999) and graduating with a B.S. in Elementary-Kindergarten Education and Pennsylvania elementary teacher certification. The EK ED students completed the SEBEST twice: at mid-semester and at the end of the semester.

The Coefficient Alpha reliability for the SEBEST at mid-semester with the URBED prospective elementary teachers was .90, .81 for the PSE sub-scale, and .88 for OE sub-scale. At mid-semester, the reliability of the SEBEST with the EK ED prospective elementary teachers was .88, .83 for the PSE sub-scale, and .85 for OE sub-scale. The reliability of the SEBEST with the EK ED prospective elementary teachers at semester's end was .92, .87 for the PSE sub-scale, and .86 for OE sub-scale.

A Person-Product-Moment correlation coefficient was calculated using data from the EK ED prospective teachers who completed both SEBEST administrations (n = 90) to determine test-retest reliability. Test-retest reliability for the SEBEST was calculated to be .70. For the PSE sub-scael it was .70 and for the OE sub-scale it was .67.

Conclusions

Based on the standardized development procedures used and the associated evidence, the SEBEST appears to be a content and construct valid instrument, with high internal reliability and moderate test-retest reliability qualities, for use with prospective elementary teachers to assess self-efficacy beliefs for teaching and learning science for diverse learners.

The SEBEST could be a valuable tool for science teacher educators working in practical and research settings to assess the self-efficacy beliefs of prospective elementary teachers with regards to science teaching and learning for diverse learners. Similarly, the SEBEST could be useful to multicultural teacher educators. For example, the SEBEST could be used to help identify if a particular course or program is achieving what it purports with regard to prospective elementary teacher preparation for science teaching and learning for diverse learner populations.

Because the construct validity of an instrument is never fully established (Nunnally, 1970), the construct validity of the SEBEST will continue to need to be studied. In the process, the reliability of the SEBEST, including test-retest reliability, should be re-examined. Norming the SEBEST may provide some insights here and will provide additional information on the SEBEST that will be useful to users. Additionally, development of a form of the SEBEST for use with practicing elementary teachers should be pursued, a project the authors are undertaking.

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Appendix A

Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST)

****

Please indicate the degree to which you agree or disagree with each statement below by shaping in the appropriate letters on the scan sheet.

5 = Strongly Agree 4 = Agree 3 = Uncertain 2 = Disagree 1 = Strongly Disagree

****

		Strongly Agree		Uncertain		Strongly Disagree
1.	I will be able to effectively teach science to children whose first language is not English.	5	4	3	2	1
2.	Girls can learn science if they receive effective science instruction.	5	4	3	2	1
3.	I do not have the ability to teach science to children from economically disadvantaged backgrounds.	5	4	3	2	1
4.	Even when teachers use the most effective science techniques in teaching science, some Native American children cannot achieve in science.	5	4	3	2	1
5.	I can do a great deal as a teacher to increase the science achievement of children who do not speak English as their first language.	5	4	3	2	1
6.	Good teaching cannot help children from low socioeconomic backgrounds achieve in science.	5	4	3	2	1
7.	I will be able to meet the learning needs of children of color when I teach science.	5	4	3	2	1
8.	Girls are not as capable as boys in learning science even when effective instruction is provided.	5	4	3	2	1
9.	I do not know teaching strategies that will help children who are English Language Learners achieve in science.	5	4	3	2	1
10.	Effective science teaching can help children from low socioeconomic backgrounds overcome hurdles to become good science learners.	5	4	3	2	1
11.	I can help girls learn science at the same level as boys.	5	4	3	2	1
12.	Even when teachers use the most effective science techniques in teaching science, some children of color cannot achieve in science.	5	4	3	2	1
13.	I do not know how to teach science concepts to children who speak English as a second language.	5	4	3	2	1
14.	Effective science teaching cannot improve the science achievement of children from impoverished backgrounds.	5	4	3	2	1
15.	I will be effective in teaching science in a meaningful way to girls.	5	4	3	2	1

		Strongly Agree		Uncertain		Strongly Disagree
16.	Children of color can succeed in science when proven science teaching strategies are employed.	5	4	3	2	1
17.	I will have the ability to help children from low socioeconomic backgrounds be successful in science.	5	4	3	2	1
18.	Children who speak English as a second language are not able to achieve in science even when the instruction is effective	5	4	3	2	1
19.	I will be able to successfully teach science to Native American children.	5	4	3	2	1
20.	Girls have the ability to compete academically with boys in science when they receive quality science instruction.	5	4	3	2	1
21.	I will not be able to teach science to children who speak English as a second language as effectively as I will to children who speak English as their first language.	5	4	3	2	1
22.	Children of color cannot learn science as well as other children even when effective science teaching instruction is provided	5	4	3	2	1
23.	I cannot help girls learn science at the same level as boys.	5	4	3	2	1
24.	A good science teacher can help children from impoverished backgrounds achieve in science at the same level as children from higher socioeconomic backgrounds.	5	4	3	2	1
25.	I will be able to effectively monitor the science understanding of children who are English Language Learners.	5	4	3	2	1
26.	Girls can develop in science at the same level as boys if they receive science instruction that is effective	5	4	3	2	1
27.	I will not be able to successfully teach science to Asian children.	5	4	3	2	1
28.	Girls do not have the ability to learn science as well as boys, even when effective teaching techniques are used	5	4	3	2	1
29.	I will be able to successfully teach science to children of color.	5	4	3	2	1
30.	Children who are English Language Learners do not have the ability to be successful in science even when the science instruction is effective.	5	4	3	2	1
31.	I will be able to help girls learn science	5	4	3	2	1
32.	White children can learn science as well as other children when effective science teaching is employed.	5	4	3	2	1
33.	I will not be able to teach science successfully to White children	5	4	3	2	1
34.	Children who are English Language Learners can be successful in learning science if the teaching is effective	5	4	3	2	1

MATH CONNECTIONS: SCIENCE AND ENGINEERING APPLICATIONS IN AN ELEMENTARY CLASSROOM

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In 1989 the National Council of Teachers of Mathematics (NCTM) introduced new standards for the teaching and learning of mathematics. These standards were intended to establish a framework to guide school mathematics learning and instruction over the following decade and included emphasis in (a) problem solving, (b) communication, (c) reasoning, and (d) connections (NCTM, 1989). Yet, in contrast to this NCTM framework, the traditional approach for teaching children mathematics focused primarily on teaching routine procedures followed by paper and pencil drills. This approach seldom encompassed authentic problem solving experiences and often lacked important connections to students' lives.

In 1998, Washington State fourth grade students participated in the Washington Assessment of Student Learning (WASL). The mathematical connections referenced throughout the NCTM standards were an integral component of the WASL. Scores from this assessment indicated that only 31.2% of Washington State fourth grade students taking the test met the prescribed standard for mathematics learning (Washington State Superintendent of Public Instruction, 1998).

Purpose

The purpose of this research was to explore science and engineering applications which would enable elementary age students to establish mathematical connections to their lives outside the classroom; to help them experience math beyond the confines of classroom walls. An additional purpose was to develop teaching strategies that offered the students relevance to the arithmetic routines which they had previously been taught and, ultimately, turn them on to mathematics rather than away from it.

Background/Theory

Teaching for understanding is essential and children who do not have a broader understanding of mathematics may lack the flexibility to deal with situations that may differ even slightly from the particular situations learned in the classroom (Burns, 1992). Consequently, without contextual relevance, children are often unable to apply mathematics outside the classroom. According to a study by Saxe (1988), children and adults required to construct mathematical strategies to solve everyday problems often did so using strategies contrasting sharply to mathematics taught in school.

Math instruction has often been characterized by the process of teaching children arithmetic: addition, subtraction, multiplication, and division of whole numbers, fractions, decimals, and percents (Burns, 1992). In contrast, the dictionary includes the following in its definition of mathematics: "the science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformations, and generalizations" (Webster's new collegiate dictionary, 1976, p. 709). Comparing past teaching practices with the given definition and the NCTM standards, it is apparent that children are often not receiving the full continuum of mathematics instruction.

Researchers throughout this century have consistently correlated sound learning with teaching practices that connect the classroom subject matter to the real world. Relevant and meaningful lessons are at the root of authentic learning experiences (Dewey, 1916)

Rettaliata (1964) argued against "compartmentalization" of academic disciplines and perceived the separation of subjects as an obstacle to progress. Children need direct interaction with mathematical ideas and concrete experiences with mathematics in the real world (Burns, 1992). Perkins (1992) addressed teaching for transfer where he described subject matters ideally relating to one another and to life beyond the classroom walls. He ascertained that when learning extends across subject lines and into the real world (i.e., when it is "transferred") students' acquisition of knowledge is greatly enhanced.

Research Questions

Our research targeted two questions: (a) How can teachers help students make mathematical connections through science and engineering applications? and (b) Will science and engineering applications effectively help students make math connections to other areas of study and to their lives outside the classroom?

Procedures

Research Participants and Context

The first author began this research at the onset of my Master in Teaching internship on January 4, 1999 and concluded the research at the close of my internship on April 2, 1999. This was my final semester in a credential and two-year masters degree program and came nearly 16 years after earning a bachelor degree in civil engineering. The second author was my science methods and research methods instructor, as well as my internship supervisor.

My research participants were 24 third grade students. The socioeconomic status of the students was predominantly middle class. The setting of my research was in a public school in southeastern Washington State. My supervising teacher in this classroom had stated that this particular group of students was her "dream class." When I began teaching these students I found them to be exceptionally well behaved. The few behavioral problems that I encountered were largely due to my own inexperience as a classroom teacher and were often easily resolved. Typically, these students arrived at school prepared and ready to learn.

Intervention

I applied a hands-on discovery teaching strategy in a third grade classroom during my thirteen-week internship. In addition, I offered visual examples throughout textbook math instruction and incorporated language, application, and full class discussions of mathematics *throughout* the school day.

Textbook lessons included concepts of plane and space figures, polygons and segments, angular classification, symmetry, parallel lines, congruence, and coordinate geometry. I presented each lesson by displaying and passing around physical examples from home and school and using open-ended questions to facilitate full class discussions.

In addition to textbook lessons, I planned and taught basic engineering concepts through a series of progressive hands-on activities. These included the following design/construction activities: (a) paper chains, (b) polygon stability using tagboard and paper fasteners, (c) structural stability using straws and paper clips, and (d) geometric shapes made from student-fabricated paper dowels. Extensions to the paper chain activity included a combined class chain, measurement of the class chain, and a letter challenging two other third grade classes to build a longer chain given the constraint of using one single sheet of 9" x 12" construction paper. Extensions to the structured stability activity included Eiffel Tower and Statue of Liberty fabrications which students opted to do on their own time. Extensions to the paper dowel activity included various fabrications which students opted to do on their own time.

Other, though often unplanned, math instruction included a variety of full class math discussions. These discussions often took place during the morning routine and were generally spontaneous talks that were prompted by student interest in specific math concepts. Topics included (a) powers of numbers, (b) roots of numbers, (c) Pythagorean Theorem, (d) history of Pythagoras, (e) areas of squares, (f) areas of triangles, (g) mean, median, mode, and range of a number series, (h) equations and graphs of straight lines, (i) fractions and common denominators, (j) fraction/decimal conversions, (k) angular measurement, (l) constant versus variable, and (m) various calculator functions.

Data Collection

Data collection included a teacher log, lesson reflections, teacher record and plan book, and samples of teaching materials used throughout instruction. In addition to these teacher-focused sources of data, field notes and samples of student work were collected.

The teacher log consisted of weekly reflections. It included responses resulting from discussions throughout the day with my field supervisor, WSU supervisor, students, parents, and other teachers. Both the log and the lesson reflections included thoughts regarding the successes and failures of various lessons and possible strategies for improving instruction.

Teaching materials varied lesson to lesson. Teaching materials included lesson plans identifying objectives, procedures, discussion questions, children's literature used during instruction, examples of mathematical applications, materials used by the students during hands-on activities, overhead transparencies used for direct instruction, student worksheets, and assessment criteria.

Field notes documented student and parent statements and their reactions pertaining to math. Field notes did not document an entire lesson or activity but focused on providing evidence of student interest and the connections they were making to the lessons.

Samples of student work were collected and consisted of students' written work including project sketches, project write-ups and conclusions, and graphing worksheets. Although students completed daily skill-building textbook assignments, the samples focused primarily on student work resulting from the high-interest application activities.

The entries in the teacher record and plan book, the teacher log, and the collection of field notes began during the first week of my internship and continued throughout the thirteen-week internship duration.

Data Analysis

The data from both the teacher log and the lesson reflections were summarized in the margin of the original documents using one- to five-word descriptors. This data was then examined for patterns of instructional strategies and ongoing planning adaptations and further reduced to four recurring categories including (a) observed methods and strategies, (b) success stories, (c) areas needing improvement, and (d) student connections and involvement.

Teaching materials used for instruction were tabulated by lesson. The materials, as with the teacher log and lesson reflections, assisted in examining patterns of instructional strategies.

Field notes were used to document student reactions and comments regarding student interest and motivation in math. These notes provided an unprompted, spontaneous form of evidence pertaining to student behavior and attitudes toward math.

The data collected from field notes were color-coded using press-on stickers, examined for emerging categories, and tabulated by those categories. These categories included the students' (a) math connections to home, (b) math connections to other subjects, (c) math connections to prior knowledge, and (d) general interest and motivation in math. In addition to the field notes student work provided evidence of interesting and unexpected math connections made by the students.

The validity of this research was protected by using the multiple sources of data identified above and reviewing all data in totality, searching for emerging patterns, and developing patterns from categories that related to the research questions.

Outcomes

How can I help students make mathematical connections through science and engineering applications? Specific strategies that enabled me to help students make mathematical connections included the following:

1. Offered real-life examples throughout math instruction.
2. Taught through demonstrations, visual aids, manipulatives and hands-on activities.
3. Presented material that was relevant and meaningful to the students.
4. Encouraged student input into problem-solving.
5. Promoted team and class building through competitive activities.
6. Consistently applied mathematics vocabulary throughout all areas of instruction.
7. Integrated and encouraged content area connections.

8. Encouraged student participation through open-ended discussions and activities.
9. Offered opportunities for students to exceed grade-level expectations.
10. Provided students with activities resulting in immediate, self-reflective feedback.
11. Reflected on lessons learned and adapted accordingly.

Strategies that I needed to improve to increase the effectiveness of my instruction included the following:

1. Including "play time" for students when introducing new manipulatives and materials.
2. Estimating lesson duration more accurately.
3. Slowing lesson pace and emphasizing lesson quality.
4. Holding students more accountable for producing high quality end products.
5. Assuring that students remained in their seats during seat activities.
6. Identifying expectations to students more clearly prior to issuing assignments.

Will science and engineering applications effectively help students make math connections to other areas of study and to their lives outside the classroom?

Science and engineering applications did effectively help students make many math connections. The results were both encouraging and convincing as students began exhibiting a mathematical awareness in their work and language.

Some student comments that confirm the connections I was striving for are:

1. *Can I take a 15 by 9 sheet of paper home so I can show my dad how I made my paper chain?*
2. *Look! Lucy {the class ferret} has a line of symmetry on her tummy!*
3. *You know the scarecrow on Wizard of Oz? My dad says that when he first gets his brain he quotes the Pythagorean Theorem!*
4. *Can we do more square roots?*
5. *Will we ever get to square roots in our book?*

6. *Ohh, can't you wait to do square roots until Tuesday? I have an eye appointment on Monday and I won't be here!*
7. *I think we can beat your class. I think we can do it if we cut the pieces skinny.*
8. *I guild this chain at home. It's very fragile so I'll have to fix it here. I used tape because it just wouldn't hold together with glue. I still need to measure it.*
9. *Can we take our Eiffel Tower home to work on it?*

They began (a) using relevant mathematics vocabulary throughout the (observable) school day, (b) selecting math activities to do on their own time, (c) coloring and adding titles to their graphing worksheets, (d) requesting additional information about mathematical concepts, (e) expressing numerical answers with units, and (f) applying basic structures lessons towards elaborate constructions.

Implications

The implications of this research teachers are significant. Carefully selecting hands-on, high-interest math activities and incorporating demonstrations and visual aids throughout instruction resulted in a knowledgeable and enthusiastic student population. Another implication was achieving a balance between teaching essential computational skills and providing students opportunities to discover math through authentic experiences. My research question was intended to achieve the latter of the two, yet I was well aware that connections would be difficult to achieve if students did not have a grasp of basic math facts. By closely observing and questioning my supervising teacher, I learned that both could be (and needed to be) implemented in order for students to succeed in math. In addition, math instruction often extended across the curriculum and into hands-on projects and full class discussions. I feel the strategies that emerged as a result of this research focus will benefit others and me in any classroom.

The results of my research align closely with the standards for mathematical connections established by the NCTM (1989) and the Washington State *Essential Academic Learning Requirements* (Washington State Commission on Student Learning, 1997). The math connections and the transfer of information addressed by the research of Dewey (1916) and

Perkins (1992) are consistent with the results of this research. My research also supports the inquiry, reasoning, and problem-solving goals proposed by the AAAS (1993).

Implications of this research for future studies might include: (a) What are the long-term student benefits, if any, of hands-on math instruction?, (b) What assessment criteria should be used for teachers incorporating hands-on math instruction in the classroom?, (c) does hands-on math instruction necessarily suggest that students are making important connections to their lives?, (d) Which hands-on activities are best-suited for helping students make connections and what makes them more effective?, (e) Will an analysis comparing students receiving hands-on instruction with students receiving textbook-only instruction indicate which teaching strategy (hands-on or textbook) is better?, and (f) Do students receiving hands-on math instruction enjoy math more and are they better able to apply math more effectively to solving problems than students receiving textbook-only instruction?

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SERVICE LEARNING AT INVENTURE PLACE: A CREATIVE MODEL

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This project brings together goals of teacher education, science education, service learning, and the informal science education setting into one arena. Among the benefits of such a project is the unique opportunity presented to preservice teachers to have real experiences interacting with children in an informal science education setting while also providing support to the various informal sites in the form of the volunteer energy, interest, and educational training.

Service Learning as a Pedagogy

For teacher education, service-learning as a pedagogy is a transforming force (Conrad & Hedin, 1982; Root, 1997; Rowls & Swick, 1999). Service-learning is a method

under which students learn and develop through active participation in thoughtfully organized service experiences that meet actual community needs and that are coordinated in collaboration with the school and community; that is integrated into the students' academic curriculum or provides structured time for the student to think, talk, or write about what the student did and saw during the actual service activity; that provides students with opportunities to use newly acquired skills and knowledge in real-life situations in their own communities; that enhances what is taught in school by extending student learning beyond the classroom and into the community; and that helps foster the development of a sense of caring for others. (National and Community Service Act of 1990).

Myers & Pickeral (1997) noted,

> service learning as a pedagogy is a strategy that has particular promise in preparing future teachers to motivate and educate K-12 students, because it incorporates authentic assessment and addresses many of the principles of learner outcomes–teacher understanding of how children learn and develop appropriate

> use of instructional strategies, instruction based on knowledge of the community change leadership capacity, and reflective strategies to evaluate their performance and impact on students (p. 33).

Sullivan (1991) argued service learning can provide a means for removing the limitations of the traditional teacher preparation program.

Service-learning provides opportunities for preservice science teachers to explore teaching as a career, learn needed pedagogical skills, and acquire professional attitudes and skills (Swick, Winecoff, Rowls, Kemper, Freeman, Mason, Janes, & Creech, 1999). For the preservice science teacher, a teacher preparation service-learning experience challenges the beliefs they have about teaching science. Also, preservice science teachers can explore their own learning about teaching science. Swick (1999) found service learning enabled preservice teachers to reconstruct their conceptions and to strengthen their competencies.

Swick and Rowls (1999) reported that preservice teachers acquired new teaching skills and confidence in using these skills as well as becoming more sensitive to the strength and needs of the children, families and people they served through service-learning. More specifically, Waterman (1997) stated "students will develop a better understanding and appreciation of academic materials if they are able to put that material into practice in ways that make a difference in their own lives and/or in the lives of other people" (p. 3). Swick (1999) utilized service-learning to reconstruct the conceptions and to strengthen the competencies of educators. Therefore, if understanding and appreciation of science pedagogical content knowledge based on National Science Education Standards (National Reasearch Council, [NRC] 1996) is an expected outcome of science teacher education, then service-learning may be a facilitative pedagogical model.

The Informal Science Education Center as a Teacher Preparation Classroom

Constructivism, as an epistemology, acknowledges that learning takes place outside of the school building and time. Therefore, science and technology centers are places where science learning occurs (NRC, 1996). The type of science learning varies from center to center.

Nevertheless, the science learning will become part of the learners' conceptual framework. Albeit informal, science and technology centers are important to understanding what science children learn and how children learn science, as well as informal curriculum and instruction. Thus, teachers of science education need to be aware of the role of informal science and technology centers.

An informal science setting could provide a rich context in which the preservice teacher could examine and practice effective strategies for teaching and learning science concepts. Ramey-Gassert, Walberg & Walberg (1994) supported the value of utilizing museums as a context in which quality science can, and does, take place. Furthermore, these authors suggested that museums could provide a unique enhancement to science literacy efforts as partners with schools through collaborative projects. Chenoweth (1989), studying teachers who attended a workshop in The Franklin Institute, expounded on the benefits of teacher training within such an informal science setting, as compared to traditional college or university based courses. She stated that it is essential to engage preservice teachers in observing, interacting and reflecting upon what is happening in the informal science setting and examining what is effective in that setting. The question of this study is a service learning project, as a collaborative venture between a university teacher education program and an informal science setting, a means (a) to challenge preservice teachers' conceptions of science education, (b) to enable preservice teachers to examine an informal science setting as a science classroom, and (c) to engage preservice teachers in instruction to elementary students in many different groupings?

Service Learning at an Informal Science Center: A Model

Description

Participants in the service learning project are excused from regularly scheduled classes for the last four weeks of the semester. The service learning project requires 24 hours of time (see Table 1).

Table 1

Division of Service Hours

Hours	Task
3 hours	Orientation to Informal Science Center
9 hours	Observing and volunteering Maximum length is no more than three hours Maximum frequency is no more than 2 observation periods per week
3 hours	Lesson implementation and support of a peer
9 hours	Lesson planning and preparation

In addition to the three hours of orientation, each participant volunteers nine hours to the informal science center on their own schedules. After each volunteer experience, the service learning participants reflect upon their observations via a listserv. The listserv requires that the participants respond to the comments, questions, and observations of their peers and that they address specific questions related to their own observations:

What did I observe?

What sense did I make of what I observed?

What type of learning was occurring?

What type of behaviors did I find the learners engaging in?

Near the culmination of their volunteer hours, participants select a lesson to teach visitors at the informal science center. The lessons or demonstrations are part of the regular curriculum of the informal science center. Upon selection of the lesson, the service learning project participants write learning cycle (Smith, 1998) lessons plans. The lesson plans must be approved by both the informal science center's exhibit or education personal and the university instructor one week before the participant may present the lesson or demonstration.

Each preservice teacher performs a demonstration or teaches a lesson to school students attending the informal science center. In addition, each preservice teacher serves as a support person during one demonstration or lesson. During another demonstration or lesson, the service learning participant serves as videographer.

Assessment.

The assessment instrument for the service learning project includes the participant's lesson planning, lesson implementation, and reflections/journaling. Each participant submits a final portfolio for evaluation. This includes (1) hard copies of all their listserv reflections; (2) the plan for the lesson that they demonstrated; (3) a video tape recording of their lesson, and (4) a final paper of personal reflections about their participation in service learning. Participants describe the science learning that takes place. With specific examples from their journal entries to support their argument, the participants describe "best practice" science teaching. Lastly, participants provide feedback comments concerning the service learning project. The Appendix contains a sample rubric for SL-IP (Service Learning at Inventure Place).

Lessons Learned from Service Learning at Informal Science Centers:

Participants in the service learning projects practiced inquiry and sense-making. Participants practiced teaching strategies in an authentic setting for an authentic audience. In all phases, from observing exhibits and guests, facilitating interactions, and conducting a lesson, these preservice science teachers tested their conception of teaching and about learning science.

Participants questioned their science learning and expressed dissatisfaction with how they learn in general. Participants described children's science learning as meaningful and purposeful and children directed and centered. Participants confronted their traditional notions of teaching. The project provided authentic experiences for preservice teachers to reflect. The participants developed a more realistic and positive perspective of themselves as science teachers. Participants experienced some of the risks and benefits related to implementing a hands-on, inquiry-based approach to science.

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Appendix

SL-IP

Service Learning at Inventure Place

An Exhibition of Mastery

This project brings together goals of teacher education, science education, service learning and the environmental science education setting into one arena. Among the benefits of such a project is the unique opportunity presented to you as preservice teachers to have real experiences interacting with children in an informal environmental science education setting. You will also be providing support to Inventure Place in the form of your energy, interest, and educational training as you serve as a volunteer.

Evaluation RUBRIC

5 points	Subscribe to SL-IP listserv
10 points	Orientation to Inventure Place (Listserv journal entry)
45 points	Observation and volunteering
	5 points/hour - Journal entry three days after observation
	3 points/hour - Journal entry >three days after observation
74 points	Lesson Implementation (**Note**: You **must** have your lesson plan approved one week before you present your lesson. There will be no exceptions)
	35 Lesson Plan(s) (Learning Cycle) for Demonstration
	5 points - Objective(s) (APS Benchmark, OH Science Proficiency Outcomes, or *Benchmarks for Science Literacy*)
	3 points - Prior Knowledge
	5 points - Safety
	2 points - Materials
	Activity

4 points - Engagement

4 points - Exploration

4 points - Explanation

4 points - Elaboration

4 points - Evaluation

30 points for the presentation (video tape)

9 points Three pluses and a wish posted to listserv

3 points each

"Teacher"

Demonstration aide

Videographer

66 points Exhibition of Mastery Portfolio

15 points - Letter of Introduction (No more than one (1) page)

(a) Describe Inventure Place including its mission

(b) Describe your involvement at Inventure Place

(c) Summaries concerning your learning about science learning and science teaching

Observation Journals (hard copy)

Orientation Entry

Volunteering Entries

11 points - Lesson Plan for Lesson(s) with post lesson reflections

Videotape recording of Lesson(s)

Three pluses and a wish

Self

Copies for other team members

15 points - Summary of Science Learning

Describe the science learning that takes place at Inventure Place. Include:

(1) General science learning

(2) Science content topics that students learn

(3) Specific examples from your journal entries which support your argument

15 points - Exit Letter

(a) Describe Inventure Place including its mission

(b) Describe your involvement at Inventure Place with reference to artifacts in the portfolio. Direct quotes from work would be most appropriate.

(c) Summaries focusing on your learning about science learning and science teaching with reference to artifacts in the portfolio. Direct quotes from work would be most appropriate.

(d) Feedback comments concerning SL-IP

PREPARING TEACHERS AS REFORMERS

Deborah J. Trumbull, Cornell University

The Hope for Reform

How do teachers learn to teach in ways that align with new reforms? Many current reform documents, for example *The National Standards For Science Education* (NRC, 1996), emphasize that the reform of science teacher education is crucial to the success of new initiatives aim to engage a wider ranger of students in learning science and that foster more in-depth understandings of science among learners. However, asking new teachers to be the standard bearers for reform places them in a tenuous position, and creates seldom recognized demands for science teacher educators. Let me explicate these two claims, then offer a solution.

Two Tasks for Reform-minded Teacher Educators

Changing conceptualizations

As teacher educators, we can think of our task as one of inducing cognitive change, as have many researchers (e.g. Stoddart, 1991; Stofflett, 1994; Stofflett & Stoddart, 1994; Aguirre & Haggerty 1995). University students begin teacher education programs with beliefs about teaching and learning that have been developed through many years of successful performance in existing schools. Many of the science classrooms in which future teachers have done well, including university classes, would not correspond to the vision of science teaching/learning promulgated in recent reform documents. Because our pre-service teachers have been successful students, they are likely to believe that the system functions well. It certainly worked for them. If we want them to think about teaching science differently, if we want them to act differently as teachers, we have to convince them that there are weaknesses in the schooling system and that there are problems and issues that must be addressed. We must help them see that their notions about good teaching may not be consonant with reform visions. We need, in short, to change their conceptualizations. The classical work on conceptual change, however, suggests that producing significant changes in an individual's conceptual ecology (Strike and Posner, 1992) is a difficult process. Conceptualizations are strongly shaped by an individual's biography (e.g. Britzman, 1986). To further complicate the field, even if we succeed in helping our pre-service teachers develop broader and more articulated views of such things as learning, science content, and indications of student ability, it is still unclear how these conceptualizations will influence their actions as new teachers (e.g. Clark & Peterson, 1986; Calderhead, 1987; Nespor, 1987; Connelly & Clandinin, 1990).

Not only do we teacher educators have to argue that there are other, and we believe better, ways to think about science teaching/learning, we have only a small time with new teachers in which to make these arguments. There is a large body of research that indicates, not surprisingly, that teachers continue to develop as teachers, especially during their first years of teaching (e.g. Huberman 1993; Loughran 1994; Levin & Ammon 1996). The work of the university teacher educators, though, is typically finished when their pre-service teachers graduate. Even when we organize various forms of in-service education we typically draw from a population with only limited overlap with our graduates. We cannot, therefore, systematically continue to foster the development of our students' beliefs and actions in the directions we believe important.

The socially constructed nature of schools

Even when we teacher educators facilitate the development of new conceptualizations of teaching and learning, our graduates find themselves in particular schools, in social situations that have evolved over time. They are still learning how to act as teachers, to take on the role of teacher. Their actions will be shaped by the expectations and responses of their students, their colleagues, and their communities. These expectations are powerful and often implicit. New teachers may become aware of them only when they violate an expectation. For example, a new teacher who decides to assign homework different from that expected will find that students, and even parents, may be resistant. For example, students who have learned how to answer the questions about monohybrid and dihybrid crosses at the end of the genetics chapter will not be pleased to have to write an essay delineating arguments used to defend eugenics. Teachers interested in helping their students learn how to construct an argument using science knowledge, or teachers who want their students to understand social implications of science knowledge, will generate resistance from students used to memorizing and reciting isolated facts.

In addition, the field of teaching is rife with dilemmas that are part of our society. Berlak and Berlak (1981) for example, used the notion of dilemma to explicate many of the tensions endemic to the enterprise of education. Must students memorize the terms used in genetics and master the dihybrid cross before they can begin to consider arguments about eugenics? Can we expect students to learn introductory genetics material better if they see its social relevance? These are not easy questions to answer – the dilemma is real. Is it any wonder that new teachers often return to their earlier notions of teaching and/or adopt the views of their colleagues, views we teacher educators might consider conservative (see, for example, Britzman, 1986)?

As a teacher educator, I could resign myself to feeling my efforts at change were futile. I find that a social constructivist view of school reality is helpful in warding off impending frustration and cynicism. One way to express some of the ideas I see key in social constructivism is to use the language of biology. Many of the assumptions underlying social science derived from the early positivists' understanding of physics, which implied directional notions of causality. When we shift to a biological notion of causality, "the images of forces, trajectories, and direct causes are replaced with thinking . . . in terms of constant change and complex interdependencies" (Davis and Sumara, 1997, p. 109). Davis and Sumara described a model of cognition that captures the complex interactions between individual and context.

> Rather, the cognizing agent is recast as part of the context. As the learner learns, the context changes, simply because one of its components changes. Conversely, as the context changes, so does the very identity of the learner. Cast against a different set of circumstances, caught up in different sets of relationships, how we define ourselves and how we act is inevitably affected. And so, learning (and, similarly, teaching) cannot be understood in monologic terms: there is no direct causal, linear, fixable relationship among the various components of any community of practice. . . . Everything is inextricably intertwined with everything else" (Davis and Sumara, 1997, p. 111.).

This view of social reality, in which there is constant interplay between one's conceptualizations and others' actions and reactions, helps us understand how difficult it is for new teachers to act on visions of reform. If we accept this view of cognition and of social reality, what do we then do as teacher educators?

Selection and Vision - How can we teachers educators act as agents of change?

As teacher educators, I believe that there are two ways we can contribute to preparing teachers who will teach in ways consistent with that envisioned in reform documents and who will be able to contribute to productive change in their schools. I think that we can carefully select teachers who are aware of and thoughtful about dilemmas, and we can encourage the development of their own vision of teaching. I present a few snippets from a longitudinal study of six teachers (Trumbull, 1999) to illustrate my points. I have chosen just two teachers for comparison. Elaine has continued in teaching from the time of her graduation in 1991, and is now the senior biology teacher at her school. George graduated in 1992, and taught for two years, then moved into graduate work in research biology. As I have talked with and reviewed interview transcripts from these two, I have looked for ways that help me to understand their career trajectories.

Identifying reflective students

Because teaching is such a difficult profession, I argue, as does LaBoskey (1994), that we need to select for pre-service teachers those students most capable of examining their practice critically. We can refer to this as being reflective. One aspect of reflectivity is the ability to examine the system in which one is acting. Both George and Elaine were very reflective in their interviews. Elaine's comments as a senior reveal her ability to think about her own education and the roles she took, and her identification as a teacher.

Before I present the quotes, let me explain the conventions I've used. I have removed habitual words or phrases such as "you know," or "kinda like" because in written speech they can interfere with meaning. I have inserted in brackets words or phrases I feel help make the meaning clear, because written speech lacks the cues of verbal talk. I put paralinguistic cues in parentheses.

DT: But you got here [to Cornell] and you continued to like biology?

ES: Yeah I liked the subject matter more than I liked the [biology] program? I didn't feel really comfortable with a lot of the pressure and everything. It's really competitive, and really big, and I don't feel (voice trails off, ends in mumble).

DT: Is that getting any better now that you're taking higher-level classes?

ES: Yeah But I think there's more than that. I'm not just a biology major any more, I'm doing other things, like education So, I go to other classes that have a different outlook. And now I don't worry so much about everybody around me. Like, I used to feel so--I don't know--lost, and "I don't know if it's all right to be in this class." And then I stopped feeling that way, maybe because I didn't have to get the best grade, or something? Not that I ever did anyway. (joking tone). But I knew I didn't have to? So then I started doing better. I think I started learning how to take those kind of classes I like--I have a smaller biology class this semester, and I really like that.

George also was thoughtful about and critical of the conditions at Cornell, particularly as they affected his learning. As a junior, he said:

GF: That's why, just the workload here turns me off. Because in a lot of my classes I would really like to get in depth, instead of covering a million things just to cover them. And not just in science. Like in German or English or something like that. I would like to look up every word I don't understand, and then maybe have time to memorize a list of words every day, or something that I didn't know It just seems like the faster you go, the more material you try to learn in a certain amount of time, you know, it reaches a limit And I think we're past the limit here at Cornell, where it just starts to hinder.

George worked one semester in an introductory biology class on campus as a senior. He enjoyed re-visiting the material in the course but was critical of the course from a curricular and subject matter perspective.

GF: There are a lot of times when I'm sitting in lecture, he [the lecturer] says something And then he'll say right after it, "Oh, but that'll make sense later." I know what it means, because I've been later. But I try to picture myself as not having had that [later experience]. And it's frustrating It's much easier the second time around Especially if you've been successful in putting it all together And I think that's something that's going to be really hard [when I'm teaching], is making an effective curriculum Because [for] a lot of things in biology it's hard to just build up from the bottom, because where is the bottom in biology exactly?

I mean, because there are a lot of unifying things Evolution's part of it DNA is another thing. I guess probably chemistry's a good start. And then people go, "I don't understand why chemistry's in biology." So, I think if it's possible to give them some sense of the Big Picture. Maybe, in biology, like... showing say, how plants and animals coexist and how there's a balance of carbon dioxide and oxygen. Showing like common threads that ties it all together at first. Then going through and reminding them periodically how this fits into the Grand Scheme of Things.

It is, I trust, clear that both Elaine and George were able to understand the system within which they were studying, and to develop critiques of the system. They could articulate ways in which the structure of classes affected their learning negatively. George also was quite insightful about complexity of biology as a field of study. There were ways, though, in which Elaine and George were quite different.

The personal vision

As a second requirement for teacher education, I feel we must work hard to help our pre-service teachers develop a personal sense of mission. But not just any mission will do. It is not enough to want to teach biology for the sheer love of biology. It is not enough to want to become a teacher able to help the maximum number of students pass required tests. New teachers must be helped to develop a deeply held sense of purpose, one that will help them deal with the complexities of schooling and resolve the dilemmas of schooling in meaningful ways. Elaine had a strong vision of her purpose for teaching. George had an equally strong vision, but his view was focused more on content and thinking.

During her first year of teaching, Elaine continued to be concerned with the amount of vocabulary often associated with biology, and wished to help students relate biology to their lives. She felt somewhat constrained by the curriculum adopted by the school. Her comments also reveal her humor and the extent to which she created different voices in talking.

DT: How much freedom do you have to decide what you're going to teach?

ES: I received a curriculum outline [that was developed by] people that taught [biology]. I had a certain amount of freedom, but I'm trying really hard not to be too bogged down in terms. I think, in biology, we always talk about all these words. I had the kids talking about what a consumer is, what a producer is, and very comfortably using those terms. Well, I look at the midterm, when I finally got it, a month through school or two months through school, they had the words heterotroph and autotroph! I was like, "Oh my God, why don't you just hit me over the head with a 2 by 4! I don't need this. The kids can communicate, and then you tell me I have to use [the terms] heterotroph and autotroph?"

Elaine was also dissatisfied with the organisms used to exemplify key phyla. She pointed out that her students, living near an ocean, should observe jellyfish instead of the commonly used *Hydra*, "Because they've seen jellyfish (her emphasis) , they've probably been stung by them!"

In an interview in her second year of teaching, Elaine's conversation illustrates how her commitments contributed to decisions she made about the biology content to address and the ways to organize the material. She had developed some idea about the story line she hoped to develop over the course of the year, so could link topics in a way that would propel that story. By deciding on the key things she hoped students would learn, she was then better able to make decisions about the amount of detail to cover, and the specificity of language she would ask them to learn. These segments also revealed her ability to monitor the cultural norms of the school and to maintain her independent thinking. Although the biology teachers met and decided what to teach, Elaine articulated clear ideas about what she felt it was important to teach in high school biology.

ES: How do I decide what I'm going to teach? [She interprets my vague gestures and grunts] Well, we have a group of biology teachers that meets. We broke down what are the really important topics that you'd want to include. I have a really hard time going through photosynthesis and all the little parts. I've never done it yet with a group and I'm waiting for somebody to yell at me, but I just can't stand it, personally.

DT: What are the little parts, like, give me (trail off)

ES: Like all the cycles . . .they [the students] forget that photosynthesis produces oxygen, when you do all that. And I'm thinking "What is the point?" But then again, I teach a lot of detail about DNA because I feel "How are they going to understand the more complex issues around genetics, which I think are important [without that]?"

Certain teachers say they feel there's a reason for teaching about all the little things that happen, all the reactions that happen in photosynthesis and respiration, but I just haven't figured that out yet. So we [teachers] figured out some topics and I've made my own pathway through the topics that we're expected to teach and re-arranged things. [For example] they think it's like this new thing, they say, "I think I'm going to teach nutrition as I teach digestion." And I said, "Yeah, I tried that, I like it." And they said, "Oh, you don't go by the book?" And I said, "Well, -- no." (laughs). Because . . . the way it's set up, just didn't make sense, so I didn't feel like I could make it flow right. So I guess I've sort of been trying to figure out the order of things, what makes sense. So that you're not. . . saying, "Remember back in September, when we went through the ribosomes?

George consistently spoke as a scientist when describing his purposes. As a junior, when he described his vision of good teaching, George focused on the biology and on learning how to learn. Although he could articulate how he wanted students to think, he did not articulate any concern for connecting the subject matter to the lives of the students.

DT: How would you describe, how would you recognize really good science teaching?

GF: I'm not sure exactly how it should be done, but I have ideas about what it should bring out in students. First of all they should learn the subject matter and they should have a Grand Scheme of things. Because I think a lot of students, just [say] "Okay, now we're doing amphibians." And they do that and they file it off somewhere and then, "Now we're doing this." and they never bring it all together. So I think it's important, at the beginning, to tell them, "This is the grand scheme of things. This is how it all fits together." And then they can, they have like a skeleton where they can put things in. And I just think if they don't have that at first, then they're going to get lost.

Later on in our conversation, he identified another goal he considered.

GF: But I think something that should come out of education is (pause) independence. Independence of the mind, being able to think for oneself and decide whether something makes sense or not. Because a lot of people [ask] "Why am I learning this if I can just look it up in the book?" Because the book isn't always going to be there - - - thinking on your feet.

In his second year of teaching, George continued to be opposed to a focus on facts and terms. He emphasized again that learning how to do science was his most important goal as a secondary teacher. I had asked him what he would do in the ideal teaching situation.

GF: I wouldn't be as concerned with just memorizing facts. They would do more projects, and we would spend a lot more time on scientific method, and designing our own experiments, and um (pause) going out and doing projects in the community or studying one particular ecosystem or something. It just seems to me that if you asked the average person who took high school biology what they remembered from it, it's probably absolute zero.

George's vision, although sophisticated, failed to link the content to any purpose for the lives of young people. He continued to be concerned that students gain some "Big Picture" or "Grand Scheme" (his terms) of biology, but provided few details about what this should be. It seems that by focusing on learning to think like a scientist, he failed to make judgments about any area of biology content that would be of greater importance in the lives of his students. In his second, and last, year of secondary teaching he commented that he had observed a colleague with many years of experience teaching introductory science. George figured out that this colleague remained fascinated with teaching because he focused on his students, observing and learning about them. George could recognize how engaging this focus was, but did not appear to share this deep curiosity about his students.

Finale

Interpretations of data from a small sample must always be tenuous. It is impossible to make generalizations in the ways in which experimental researchers do. However, by having rich detail from these two young teachers, it is possible to identify differences that provide a plausible explanation for their career choices. Both Elaine and George were thoughtful and critical, able to examine their contexts and evaluate them based on some explicit criteria. They both had a love of biology. What distinguishes them is the sense of mission they developed. Elaine's mission helped her to resolve many of the dilemmas of schooling. When deciding on content, she referred to areas that she believed were of most importance to the lives of her students. She observed that learning details in some areas actually seemed to prevent understanding of fundamental concepts. She formed a view of how she wanted the year of her work with her students to progress, and began to revise her course based on her overall image of how her students would learn and develop over that year.

George's concern that students develop habits of scientific thought implies a complex and sophisticated view of the content and epistemology of science, but held little hope for resolving the dilemmas inherent in schooling. By focusing so strongly on learning to think, he paid less attention to the organization of content. His view of the complexity of biology and the interdependence of its many areas was exciting for me to hear as I interviewed him. However, this view of biology, coupled with his failure to consider topics that were important for adolescents to grasp, left him with no criteria for making decisions about what content to teach or how to develop his course.

As science teacher educators, we hope that our students will have a rich understanding of their subject matter. We hope, too, that they will be concerned to help their students think in more disciplined ways. These two areas are not enough, though. We cannot forget that teaching is a moral profession, one that requires professionals to have a vision of how they wish to change the lives of their pupils. Elaine had such a vision, and it helped her to make curricular and pedagogic decisions. George did not have such a vision, and thus could not resolve curricular dilemmas. These ideas are implicit in common truism that there are two kinds of teachers, those who teach a particular subject matter and those who teach children. Like many dichotomies, this one is unhelpful. Elaine's commitment was both to subject matter and to students.

When we select students for per-service teacher education, we can work to select candidates with at least an embryonic vision that the subject matter they teach has the potential to contribute to the development of their students' lives. Many of the standard elements in pre-service teacher education programs provide opportunities to work with students to help them develop their own strong visions of being a teacher. For example, I think that we can nurture that vision by providing them experiences with youngsters that require them to attempt to grasp the perspectives of these youngsters, to understand the world as experienced by these youngsters. Courses in adolescent psychology can also contribute to the ability and desire to understand the lives of learners and a theoretical framework from which to do so. In addition, in our methods courses and student teaching supervision, we can ask pre-service teachers to explicate how the subject matter lessons can contribute to the lives of youngsters. We can help them to articulate a purpose for teaching larger than merely mastering some specific body of knowledge or style of thought. We, of course, must do the same in our work as teacher educators.

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A THEORETICAL FRAMEWORK FOR EXAMINING PEER COLLABORATION IN PRESERVICE TEACHER EDUCATION

Christopher Andersen, Ohio State University

The Newark campus of the Ohio State University prepares prospective elementary classroom teachers through a five-quarter M.Ed. program which includes two quarters of field experience and one quarter of student teaching. Integral to the field experiences and student teaching is *peer coaching,* a collaborative technique in which pairs of student teachers provide feedback and support to one another. Though some peer coaching programs like OSU-N's have shown positive benefits (Erchick, Kent, Kos, Bendixen-Noe, & Andersen, 2000), the preponderance of research does not find any benefit of peer coaching over self-assessment in terms of effective use of teaching skills in the classroom (Franklin, 1981, Turner, 1981). Clearly, there is a need for more research to look for specific factors that distinguish the successful and unsuccessful peer coaching approaches.

The education literature on peer coaching has yet to mine a potential motherload of previous research: the substantial body of psychological studies on the effect of group interactions on cognitive development, especially research on peer collaboration in children (see Azmitia & Perlmutter, 1989, for a review). The purpose of this paper is to link the practice of peer coaching in preservice teacher education to the substantial research literature on children's peer collaboration.

A Taxonomy of Benefits of Peer Collaboration

The benefits of peer collaboration in children can be categorized into a three-level taxonomy (Andersen, 1998). At the simplest level *(observation)*, collaborators are exposed to ideas other than their own (Piaget, 1932, 1968). Research in scientific and everyday reasoning (ex., Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, 1991) has shown that subjects often have difficulty generating ideas that conflict with those they already possess. Even if they can generate alternate ideas to consider, they may not be able to hold them simultaneously in memory. At this level of benefit, individuals may receive fresh perspectives by working with a partner.

The second level of benefits occur at the level of *interaction,* in which subjects give and receive feedback about the use of a teaching strategy. Most of the research on peer collaboration has focused on benefits at the observation and interaction level. Little attention has been devoted to the benefits that occur at the third level of benefits, the *metacognitive* level, despite the increasingly important role that metacognition plays in explanations of individual acquisition of academic skills and content knowledge (e.g., Kuhn, Garcia-Milà, Zohar, & Andersen, 1995).

Metacognitive and Metastrategic Knowledge

Reasoning in individuals has been conceptualized by Kuhn (1991) as an internal argument. In her own research on causal reasoning, this argument takes the form of a mental debate in which causal theories and supportive evidence are evaluated and compared.

Another type of internal argumentation occurs when teachers (or any expert) employs the skills and strategies of their field. When a teacher presents a lesson, she has an array of strategies at her disposal. Through training and practice, she has acquired *performance level* knowledge (Kuhn, in press) about these strategies. When presenting a science demonstration, she knows to activate students' pre-existing knowledge about the topic, for instance. Historically, methods classes have often focused on imparting performance level knowledge to educators, giving descriptions of strategies and providing practice in their execution.

But how do educators choose which strategy from their repertoire to employ? Research in cognitive psychology has focused greater attention at the various forms of metacognitive knowledge that experts possess about their own thinking. *Metastrategic* knowledge (Kuhn, et al., 1995), for example, includes information about the effectiveness and applicability of various strategies. In the previous example, why did the science teacher choose to do a demonstration rather than a lecture or student laboratory? Presumably, she engaged in an internal argument that involved a debate of her metastrategic knowledge of the pros and cons of various teaching approaches.

Metastrategic Knowledge and Peer Coaching

Andersen (1998) proposes several metacognitive benefits to peer interaction in children that are applied to preservice teachers in the present study. Previous research (e.g., Kuhn et al. 1988, 1995) has shown that an individual's use of cognitive strategies is swayed by idiosyncratic biases in exploration caused by the unique metastrategic knowledge that an individual brings. This has been cited as an explanation for the experimental findings suggesting that the challenge in becoming expert in a domain lies not in the acquisition of new skills but rather in the development of the metastrategic knowledge that governs the individual's use of those skills. In teacher education, this suggests that even though teachers may have a repertoire of teaching skills at their disposal, what separates expert teachers from others is their well-developed metastrategic knowledge about these teaching skills that allow them to select the appropriate teaching strategies for the situation. One metacognitive benefit to peer coaching is that it allows an individual to be exposed to metastrategic knowledge different from their own.

One approach to studying peer collaboration views the verbal interaction between partners as an externalized form of the internal debate done by solo individuals. This debate becomes a form of *distributed metacognition* (Andersen, 2000) in which the elements of reasoning are shared among the group members. Another metacognitive benefit to peer collaboration lies in the sharing of the cognitive demands of juggling a new strategy and its accompanying metastrategic knowledge. In peer coaching, this allows partners to share the cognitive load until the strategy and metastrategic knowledge are individually consolidated and more easily implemented individually.

This consideration of the group interaction as a single cognitive entity allows the application of principles of individual cognition to group processes like peer coaching. For example, another metacognitive benefit is accrued as each partner in a peer coaching pair provides a check for regressions from new strategy use to old habits due to unstable metastrategic control. The partner's feedback becomes an external version of the internal metacognitive argument that occurs when a strategy is selected for from an individual's repertoire. The intercession of a peer coach helps support an individual's faltering metastrategic debate concerning the advantages and disadvantages of various strategies in the individual's repertoire. This *metastrategic reinforcement* provided by a partner may account for the improved performance of the pair condition over the single by these two dyads compared to the other subjects. Therefore, a peer coach is presumably giving feedback about not only teaching strategies, but also about the metastrategic knowledge that are being used to select teaching strategies. This metastrategic level is commonly seen in peer coaching when conversation fosters reflection about the lesson. As a result, peer coaches examine not only whether the preservice teacher can do a particular skill, but also the metastrategic thinking underlying the student teachers' choice of skills to employ.

"Meta-metacognition" and Peer Coaching

A further consideration in peer coaching is the issue of how to improve participants' coaching ability. For teachers, the effective use of strategies requires not only performance level knowledge of the strategies (how to do the strategies) but also metacognitive level knowledge of the strategies (when and why to do the strategies). Reflection on one's own teaching practice is one method to develop one's metastrategic knowledge on strategies.

The process of peer coaching serves to foster reflection in two ways. First, the hectic daily routine of teachers requires teachers to think reflexively rather than reflectively and prevents little thinking about one's practice beyond the immediate implementation of strategies. Peer coaching sessions provide a scheduled opportunity to step out of the reflexive mode and think reflectively. Second, the peer coaching process allows the externalization of thinking that is normally internal and makes that thinking more available for examination.

One goal of peer coaching is to improve this self-reflection process. This requires coaches to think about the coaching process itself–reflecting on self-reflection, for example. This "meta-metacognition" is a level of thought that has not been addressed in the peer coaching literature but may be the key to explaining the differences in effectiveness in various peer coaching programs.

Conclusion

Peer coaching has had inconsistent success in improving preservice teaching. One explanation may be the lack of attention paid by researchers and teacher educators to *teacher metacognition.* Expert teachers are distinguished from novices by their metacognitive knowledge of the field (particularly metastrategic knowledge). In addition to the performance level skills typically taught in methods courses, preservice teachers need experiences to foster the growth of the metastrategic knowledge associated with those skills. Peer coaching has the potential to contribute to that metacognitive growth (1) by exposing partners to metastrategic knowledge different from their own, (2) by sharing the cognitive load of newly-acquired thinking through distributed metacognition, and (3) by providing metastrategic reinforcement of one another's faltering metacognitive control of new cognitive processes. Peer coaching provides a scheduled time for participants to think reflectively instead of reflexively and makes the internal processes of reflection explicit, external, and available for examination. Improvement of peers' ability to coach may lie in their metacognitive knowledge of these metacognitive benefits ("meta-metacognition").

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PROFESSIONAL DEVELOPMENT: WHAT IS WORKING IN THE STATE OF NEVADA.

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Background

Professional development has been a large part of the science education field for quite some time. Since the release of the National Science Education Standards (NSES, 1996), professional development in the form of in-service (or re-training practicing teachers) to meet both process and content science standards have burgeoned. The National Science Foundation (NSF) and much of the Dwight D. Eisenhower (DDE) money for higher education, as well as many other funding agencies and programs, have funded numerous national, statewide, and local programs.

With this increase in professional development have come scrutiny of previous professional development models. Traditional modes of professional development, "lectures to convey content and technical training about teaching"(p.56) were criticized by the National Science Education Standards (NSES, 1996). Criticisms of professional development programs stem from as early as Karplus and Thier (1967), to numerous articles (Cook, 1994; Darling-Hammond & McLaughlin, 1995; Howe & Stubbs, 1997; Wallace, Nesbit & Miller, 1999), to entire books on the subject (Tobias, 1990; Mandy & Loucks-Horsley, 1999), just to reference a few. Howe and Stubbs (1997) eloquently surmise the situation by stating:

> It seems clear that past and present methods and approaches to continuing professional development for teachers have not produced the desired result and that new methods and approaches are needed. If we continue to do the things we have always done, we will continue to have the results we have always gotten - and these results are not serving us well" (p.168).

The standards called for reform in professional development and "if reform is to be accomplished, professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding and ability" (p. 56). Although the NSES (1996) outline components that "Professional Development" programs should include, there is still a considerable amount of research in the literature on what and how professional development programs should be structured and conducted.

The literature reveals that many of the "new" forms of professional development have coincided with the rise of new programs such as Sci-Link (Anderson, 1993) , Project LIFE (Radford, 1998) and the GLOBE project (Pyke, 1999). Several models of professional development have been outlined as a result of these programs. Howe and Stubbs (1997) wrote about a constructivist / sociocultural model of professional development, Radford (1998) proposed a model of professional development in life sciences, and Wallace, Nesbit, and Miller (1999) wrote about six different leadership models in professional development that were developed by looking at 15 professional development programs over time in North Carolina.

All of these models have some commonalities; specifically, there was an intensive summer workshop ranging from two to three weeks, a project of some sort for the participants to work on, and academic year follow up. The programs included methodologies such as small group work, hands on activities, constructivist learning situations, and utilized scientists in the field content area of research. These are the components that good science instruction and professional development should include and are recommendations and/or suggestions advocated by the NSES (1996).

Purpose

The purpose of this research is to explore Nevada Operation Chemistry, a professional development program in Nevada, to see if there was any impact on teacher efficacy, outcome expectancy, teacher attitude on teaching physical science curriculum, the general effectiveness of the program, and if there was any effect in a select group of classrooms.

Problem

Professional development has been a large part of the science education field for quite some time. Since the release of the NSES (1996), professional development in the form of in-service (or re-training practicing teachers) to meet both the process and content standards have burgeoned. The National Science Foundation (NSF) and much of the D. D. Eisenhower money for higher education, as well as many other funding agencies and programs, have funded numerous national, statewide, and local programs.

The state of Nevada, like most other states, has recently written statewide science content standards and performance standards/assessments which not only require that teachers teach certain concepts/topics by the benchmark grade levels, but are now receiving performance tests for the children in their classrooms, which now make them accountable for the science content. With this latest legislative action, some funding came from state appropriations in the legislative session, but the great majority of the retraining of the teachers still comes from entrepreneurial efforts related to diminishing funds from government agencies. With this influx of money and expansive base of initiatives, workshops, and programs, one must wonder what effect those programs are having on both the classroom teacher and the students in the elementary classroom.

Research Question

Did Nevada Operation Chemistry have any effect on classroom teachers efficacy, attitude and general disposition in teaching chemistry related science and what impact has it had on their classrooms?

Program Description

This research focuses on a national program that co-evolved with the Benchmarks, Project 2061, and the advent of the National Science Education Standards. Operation Chemistry (Op Chem) which was originally funded by the National Science Foundation (NSF) in conjunction with the American Chemical Society (ACS) was a five year effort that was designed to enhance the chemistry and chemical education literacy of teachers of grades 4-8 throughout the nation. Nevada Operation Chemistry, based upon the national Operation Chemistry model, is a program designed to enhance the conceptual and activity-related chemistry understanding of K - 8th grade teachers and pre-service teachers throughout the state of Nevada. Specific goals of the program are to (a) instill in participants a sense of confidence about their ability to learn and teach chemistry in a hands-on inquiry manner in accordance with National and State Science Education Standards; (b) foster professional growth, including presentation of content and methodology to peers in school, local, state, and national settings; (c) make participants aware of the relationship between chemistry in the school, university, community, and industry; (d) nurture the sense of community and collaboration among participants that is possible with an intensive, long-term program.

Nevada Operation Chemistry is a cooperative effort between the University of Nevada, Reno, College of Education, Chemistry Department, Biology Department and School of Medicine, Nevada State Department of Education (Science), Washoe County School District, Douglas County School District, Clark County School District, Humboldt County School District, Lyon County School District, The Nevada Rural Alliance, Newmont Gold Co., Cyanco, Eldorado Hotel-Casino, Brew Brothers, Nevada Mining Association, Women in Mining Educational Foundation, and Sierra Nevada section of the American Chemical Society.

Nevada Operation Chemistry has been primarily funded by the D. D. Eisenhower monies for higher education in the state of Nevada along with substantial donations from industry, businesses, and education associations totaling over $180,000.00 over the past three years and has trained more than 156 teachers.

The workshop is currently set up as a summer course where teachers are brought to the University of Nevada, Reno for a two week intensive workshop and field trip, a long term project/presentation to be made by the participant, and a follow-up workshop during the late Fall. Housing, per diem and mileage is provided for participants traveling from out of town. Tuition for graduate credit (3 credit hours) is paid by the program for all participants.

The workshop began at 8:00 a.m.each morning with a continental breakfast and a group review of the previous days activities. The participants then attended a morning session from

8:30 - 11:00 a.m., attended a lecture from 11:00 - 12:00 p.m., took a lunch break from 12:00 - 1:00 p.m., attended an afternoon session from 1:00 - 3:30 p.m., and then met as an entire group for reflection on the day from 3:30 - 4:00 p.m. This took place daily except for the field trip days where we left on Tuesday afternoon and drove to Winnemucca, Nevada (Viewing mining chemistry videos along the way), gathering in the evening for a dinner and lecture. Wednesday the day began at 7:30 and tours of Cyanco and Newmont Gold took place and kept participants busy until 5:00 that evening at which time we met for a catered dinner and speaker. Thursday morning we headed back to the Newmont Gold Lone Tree Mine where we ran two session in the labs at the mines. We left late that afternoon and returned home by 7:00 p.m. that evening. In all, the two week workshop entailed 60 hours of formal instruction and a minimum of 11 hours of group discussion time.

The participants then go back to their classrooms and teach science adding Nevada Operation Chemistry activities to their current curriculum (which was part of the workshop of finding where and how the content and activities fit into their standards and curriculum). All the while they are working in teams of 2 to 4 in designing a professional development experience for teachers in their schools or districts. The professional development that they develop and teach is then shared at a follow up session (usually in late November) back at the UNR campus for an intensive one day follow up experience.

The total impact of Nevada Operation Chemistry (1997, 1998, 1999) to the State's teachers at well over 763 hours of instruction by our graduates (of the Operation chemistry program) to other teachers (teachers training teachers model) in inservice training and workshops impacting over 1526 people in over 53 different school settings in Nevada. Nevada Operation Chemistry workshops outside of Nevada have now impacted 12 other states, and over 1000 people. These numbers do not include the numerous hours of science teaching that takes place on a daily basis in each one of these teachers' classrooms

Primary instructors for the workshop involve college instructors (Education, Chemistry, Medical School, Biology), District Science Coordinator, industry scientists, classroom teachers, and graduates of the previous years' Nevada Operation Chemistry programs.

Methodology

Quantitative

This study utilized both quantitative and qualitative methodologies. The quantitative design for this study is a modified single group pretest - posttest design (Campbell & Stanley, 1963). The *Science Teaching Efficacy Belief Instrument* for in-service teachers (STEBI-A) (Riggs & Enochs, 1990) was administered as a pretest, on the first day of class, on the last day of the two week seminar, and then again at the follow up workshop 5 months after the 2 week course.

Additionally, Terra Nova (standardized test used in Washoe County School District) scores were investigated from a select group of participants (from the same school) to see if the science scores improved from the previous year to the present year in these participants classrooms.

Qualitative

The qualitative methodology used to gain insight into Nevada Operation Chemistry was through the use of focus groups. Focus groups have been used for many years in different settings. Initially defined as group interviewing, this technique was used in business, industry and politics to get a better understanding of people's thoughts on problems or issues. The name "focus group" was coined by Merton, Fiske and Kendall in 1956, "to apply to situations where the interviewer asked group members very specific questions about a topic after considerable research was compiled" (Fontana & Frey, 1994, p. 364). Focus groups are a form of qualitative research in which groups of eight to ten people are purposefully sampled from a larger group and asked several open ended questions. Particular methods to focus group interviews vary depending on the purpose of the research. However, Fontana and Frey (1994) point out that there are three skills that are needed in order to conduct a constructive session: (a) the interviewer must keep one person or small groups of people from dominating the conversations; (b) The interviewer must encourage recalcitrant respondents to participate; (c) Responses must be elicited from the entire group to ensure the fullest possible coverage of a topic or issue. Wanat (1993) produced guidelines in focus group research including: (a) an introduction to this type of research and group rules; (b) a discussion of two open-ended questions; (c) a request for new ideas; and (d) a summary of key points. With this methodology in mind, Fontana and Frey (1994) state that, "the group interview has the advantages of being inexpensive, data rich, flexible, stimulating to respondents, recall aiding, and cumulative and elaborative" (p.365).

Additional qualitative data was collected through journal entries, exit interviews, and final evaluation papers. The data collected resulted in large amounts of thick and rich descriptive information. Bogdan and Biklen (1992) state that, "As you read through your data, certain words, phrases, patterns of behavior, subjects' ways of thinking, and events repeat and stand out" (p.166). Using the qualitative form of data reduction process, as described above, thick and rich descriptions were developed and put into 15 different themes.

Results

Quantitative

Results of the ANOVA procedure on the STEBI-A scores personal science teaching efficacy scores were not found to be statistically significantly different. Outcome expectancy scores can be found in Table 1.

Table 1

Analysis of Variance of Operation Chemistry Outcome Expectancy Scores

Groups: Pre-workshop, post-workshop, follow-up workshop.

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A (...)	2	278.4816	139.2408	5.06	0.0083	ERROR
ERROR	90	2475.648	27.5072			
TOTAL(Adj)	92	2754.129				

Due to the significant results of the ANOVA, a Scheffe' Multiple Comparisons Test was performed upon the groups. Results of this procedure can be found in Table 2.

Table 2

Schefee Multiple Comparisons Test for Differences

Groups (A,B,C)	Mean	ABC
Pre-workshop (A)	42.02	. . S
Post-workshop (B)	44.63	. . .
Post-workshop (5 months after) (C)	46.28	S . .

Note: An "S" above signifies a statistical difference between groups at the .05 level or less.

Qualitative - Focus Group

There were 15 interesting (salient points) themes that emerged from the focus group discussions. They are listed with some samples of responses from participants for each theme.

1. Teachers like to feel like they are valued - treated professionally.

> I'm being valued as a teacher that is worth the resources that are being brought to

bear to make me a better teacher, and I really appreciate that.

> For once a ray of sanity, and I felt like I was treated as a human being. Just not your typical of the UNR process.

2. Teachers liked having the binders with detailed lesson plans and materials lists for all of the activities - this prevented them from having to take unnecessary notes and concentrate on the activities and learning.

> I liked having the binder. . . having all of the activities for me to review before we actually came in the class.
>
> You don't have to waste your time taking notes. You can fully immerse yourself and enjoy it like the kids would and then see what you were learning." I mean you would still take notes, but the activities were all there in the order and detail that you would do them - so the notes that you were taking were not on how to do the activity, which is what I usually worry about, but rather on interesting things that I was learning from doing the activity.
>
> I think having all the proportions and everything there and doing them exactly the same in the class so we didn't have to take our own notes either ... like, say here are some in the binder and here's some others we're going to do.

3. Teachers enjoyed having a variety of instructors each day with different learning activities.

> I've enjoyed all the different teachers who have come to teach us. I love rotating between a teacher in the morning and a teacher in the afternoon, getting different personalities and then having you come in, having past teachers come in and teach us. It's been enjoyable because you never know who you're going to get, and everybody has their own personality in a classroom and that's always fun.

4. Teachers need some down time in order to reflect and think upon the activities that they experienced.

> There's so much given to us in the morning and the afternoon, usually there's two different labs and there's a speaker in the middle. You have very little downtime to try to

> assimilate all the information that's been given to me.
>
> One of the dislikes . . . I know we're adults and we can work really fast, and it's not really like the downtime you were talking about, but we're doing one thing and then doing another . . . we're doing so much that I'm not able to absorb as much. I know I also need to sometimes close my ears and read so that I can concentrate on what I'm reading and really understand it, not just read through it.

5. Teachers enjoyed having activities that were practical.

> I liked all the activities we did using food, the things that we did were hands-on and had to do with food - which really translates into the classroom. The kids really enjoy doing those kinds of activities.
>
> It's really great to find chemistry for me to be more user-friendly, you know. It's not the scientist, the mad scientist, type thing now. It's something that I can take into the classroom and have some fun with. The kids do a lot of observations at that level, and they've given us so much that the kids can observe and do.

6. Teachers enjoyed and valued having activity materials that were readily accessible for them to buy (grocery store science).

> I feel every attempt has been made to present the chemistry in a manner where we can get supplies, and like he mentioned, like Albertson's chemistry. Things that you would have at home without great expenditures. . . .
>
> I say by and large the things we have done are things we could go out on our own, and we could get and could reproduce at a minimum of cost, and not too much trouble trying to track down where I would buy things. And that's really appreciated because this is one small area of science. I know it's the "be all, end all," but we've got the same thing in language and in reading and in social studies and in math, and there's only limited amount of money we can spend on all this stuff, and I appreciate being able to use graham crackers, being able to use balloons . . . things that I feel are cheap that I could get.

7. Teachers love learning content when it is taught at developmentally appropriate levels (for them and their students).

> The thing that I really enjoyed is . . . I love content. It's always my big thing. I love the content that's going with the experiments, not having a strong science background and trying to give that to my students, I struggle with that. I can say, "Yeah, that is the coolest experiment. Why does it work? Well, they didn't tell me that part. I just know that this is a really great experiment." And the best part that I've enjoyed is that the content goes with the experiment. You take the time to explain it that you can go back to your kids and tell them exactly what's happening and why it's happening.
>
> Content is very accessible to us in this class. So it's very easy . . . we can rest easy about how we're going to understand it. And kids learn through play, and content is made very, very accessible.

8. Physical considerations of participants must include: temperature, breaks, assimilation time, places to sit and or stand, background noise, lab stools.

> It's just a temperature thing. We've been really cold in the lecture room.
>
> I really enjoyed the whole Operation Chemistry so far, but the one biggest thing was standing for almost two hours over at the El Dorado. That was like ... I don't know about you guys, but that was just unbearable.

9. Teachers need time to share with one another and share their ideas that they do and use in their classrooms.

> I think one of the most eye-opening things . . . I've been teaching for a hundred years, and I have gone to a lot of these things . . . it is amazing because I've done ice cream with the kids, I've done root beer, I've done yeast, but mostly I haven't even, "dah," used the Zip-lock baggies. Everyone can make his or her own. I can't believe it. I use baggies at home all the time. I use the freezer bags, I use all these, but it never occurred to me to make it with them. Each kid has his own.

10. Teachers need more time to adapt lessons to their curriculum.

> I've kind of enjoyed that even though a lot of the experiments, the way they presented them, have been in a particular grade level, maybe fourth and above . . . you know, I teach the primary grades . . . they've taken time to say, you know, "This is how we can adapt it. This is how we can use it in lower grades." Where they make it fairly clear that, "We're showing it to you at a higher grade level," but just the way they present it, it's easy to see how you can use it at a lower grade level.
>
> Kind of see it for me on the other end. I teach high school, and I came to this specifically in hope to get something I could use with my freshman. And a lot of the activities would be pretty easy to bring them up to that level.

11. Follow-up workshop was necessary to bring the learning experience to a full circle

> I think the follow-up, coming back in November and having to do the workshops or the family night with other teachers - I think that's wonderful. I think that's what's forced a lot of us to really do it. Because it's nice to have all this stuff and two weeks to be over, but we have to do this other part. And that's nice. Because then we get to show everybody, and then we're the knowledgeable one in front of the parents or the teachers we teach with or whoever we decide to do that with, and then we get the cool lab coat !!

12. Stipends for materials enabled teachers to do more hands-on activities where they wouldn't have had the resources to do so without it.

> I would never have been able to do this stuff in my classroom with my school budget - the stipend enabled me to actually do some of these activities in my classroom... and surprise - they loved it and it worked!!

13. Teams from schools was a must to continue with trying new things during the year - they acted as a support group in times of trial and when other teachers / administration are not supportive of change.

> My school is very traditional and you know, those -- I won't say old, but more "experienced teachers" sort of frown on you when your class is noisy or when you are

like doing something very active and exciting . . . . I even have to convince my principal that this was what was taught to me at UNR and that it is ok. Anyway, it is easier when I am working with Lorie and Deborah because you know we have been through the program together and we support each other. We even plan lessons together and make them big events for the school.

This has been really great, because, well, there are not a lot of people out here to work with (Very rural area in Nevada) and now I get to go to Crescent Valley and they get to come over here (Starr Valley). We even did our Family science nights together - which wouldn't have happened if we hadn't worked together.

14. Administrators should be added to teams for duration or partial duration of workshop.

Hey, principal. Do you want to jazz up your science program, and get some funding?

We've got to get the administrators involved. If we don't get them excited about it, we come in and we're real excited, and they may give us permission to do something for the teachers, but if they're not going to buy into it, the minute they come into your classroom and you're doing something, they're going to think "Oh, am I on task or what ? Well, they're not.

I think getting the administration involved is great, because I know that my principal comes in . . . and my school is only 250 kids K through 8, so it's a really small Catholic school. And she comes in and she's so excited when we're always doing stuff and brings people on tours, and says, "Look. We're doing these. We're making circuits," and we're doing all this great stuff. But purchase orders are refused all the time. "Why do you need this? Can't we do it some way else?" And so, I think involving them and letting them know how great it is or having some of these key people that are teaching share this with them . . . .

15. Every teacher said that the experience was exciting and fun.

This is awesome ... chemistry's awesome!!!

> I was so excited about the stuff that we've learned and that chemistry doesn't have to be this, you know, complicated moles into grams and, you know, this shell and shell, and that chemistry is just an everyday thing. And so it's going to be really fun just seeing the kids' lights going on and going, "Oh, yeah." So I look really forward to using these labs.
>
> Kids become passionate about what you're passionate about. That's why when you have a teacher that really loves social studies and does a great job in social studies, and so inadvertently the kids end up loving social studies because you teach with that passion. So as you learn more about science and you have a passion about science, you automatically portray that to your children as you teach to them. So I'm going to foster something in them that I've been working to improve upon and that I'm excited about, they are therefore going to become excited about it. And you can go back ... everybody can go back ... my teacher was so good at this. You'll have teachers that want to start teaching because they're really good at science.
>
> You know, I feel like I've gotten a tremendous amount of stuff that I can use in my classroom, and when I can take these, whether it's forty different activities or whatever the number is, I can take those forty things back to my room, and that's forty more additional things that I can do. And if I can get another forty next year, boy, I'm here.

Conclusions

Quantitative results revealed that participants did not significantly differ in outcome expectancy beliefs during the two weeks of the Operation Chemistry intensive workshop (pre-post). There were, however, significant differences revealed between post-test scores and workshop follow-up scores taken five months later. This suggests that the treatment (e.g., science activities, labs, field trips) during the workshop by itself was not nearly as influential as were the actual teachers teaching experiences back at the schools in classrooms and different professional development seminars run by the teachers over the five months leading up to the

Operation Chemistry follow-up meeting. Effect size was calculated to be .71 (reject practical significance if < .33) (Borg, Gall & Gall, 1993). Borg et al. state that "an effect size of 1.00 is twice as large as effect size of .50. The mean of the effect sizes . . . can be calculated to yield an estimate of the effect of the experimental program or method . . . "(p. 171). Therefore, according to Borg et al. one could argue that the effect of the five month experience teaching science to children was roughly twice as "effective" as the two week Nevada Operation Chemistry workshop experience. It follows, then, that in order for science educators to begin to influence the long term outcome expectancy of practicing teachers, not only might teachers need rich and exciting experiences in learning more constructivist-based science lessons, but also supervised and evaluated experiences in teaching those same, or similar, lessons to children, peers, and parents back in their schools. From this type of continued positive support, it appears that a teacher's outcome expectancy regarding a child's abilities in the science classroom can be both enhanced and sustained over time. Qualitative results also supported the quantitative findings. Results from the focus group (points 9, 11, & 13) support that working in teams and continuing activities throughout the school year added greatly to their continued level of outcome expectancy.

Other qualitative information allowed insight into some very interesting points. The fact that teachers didn't have a significant gain in efficacy was, possibly, due to the fact that these teachers entered into the program through a competitive application process and entered at an already elevated efficacy score on the STEBI A (See results section). However, although the test may not have been sensitive enough to measure efficacy gain on the 13 questions relating to efficacy, the statements in journal entries, focus groups, exit interviews, and final evaluation papers noted that every teacher really enjoyed the workshop and as a result added a number of activities to their repertoire of science investigations as well as constructed both content and process knowledge that they did not have before.

An interesting thing that was also found was that the teachers almost unanimously mentioned that receiving the 150 materials stipend was absolutely necessary in order to implement these activities in their classrooms. Many discussions and comments revealed that the individual levels of funding in their own classrooms seriously impaired their ability to implement hands-on activities directly relating to the lack of funding in their classrooms and the expense of consumable materials. This is a very important statement because the money that is going to professional development has not really been used for materials costs in classrooms. In fact, the NSES call for reform and hands-on inquiry, but lack the same amount of emphasis on how this will be funded in classrooms which are seriously deprived of funds for materials for all subjects consumed in activity based instruction throughout the entire year. This is also a problem with school districts who are trying to change from a text to a kit curriculum. The kits come in at similar coasts, but the refurbishing of consumable materials has often been overlooked and been the demise of teachers' continued use of the kits.

Finally, administrators must be involved. The NSES state this as well as other initiatives. The problem that we find is that administrators don't have the time, even if they had the interest in attending a two week workshop, and are often hard pressed to attend even a one day workshop. How are we to perpetuate change in the classroom when administrators are not able to experience the amount of sustained inservice training that it takes to bring about change? Based upon both qualitative and quantitative research, Nevada Operation Chemistry has been truly successful in changing pre-service and practicing teachers' attitudes and overall efficacy, in the form of outcome expectancy, in the teaching and learning of chemistry and general physical science in their classrooms. Participants have learned chemistry content and process skills related required to comprehend chemical understandings in addition to becoming more aware of chemistry and environmental/industrial concerns and contributions to the State of Nevada. Every teacher that attended the workshop said that they were teaching more science in their classrooms as a direct result of the Nevada Operation Chemistry workshop. This wasn't due to just a two week course, but the addition of long term projects dealing with putting the teachers in the teaching situations over time. The teachers became the content specialists and taught children, other teachers, parents and community members the value of chemistry in their lives through hands-on inquiry learning situations which lead to the success elevated and sustained outcome expectancies in this program.

Although much research is still being done to determine the impact of Nevada Operation Chemistry, our study has shown that over the past three years that student test scores in science have improved in six classrooms (all at one school) of our Operation Chemistry graduates. At that same school there has also been an overall increase from 48 to 62 percentiles of Terra Nova (Standardized State test) scores at the school. This is very interesting data as it demonstrates how a core of teachers that are willing to learn content science as well as more effective ways of teaching science can have such a huge impact on a school population of both other teachers and students in science. The impact to Nevada's elementary, middle school, and high school students has yet to be determined from all of our graduates, but all participants unanimously said that they taught more science more frequently in their classrooms and used more hands-on inquiry teaching strategies for instruction in science and chemistry / physical science curriculum.

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YOUNG CHILDREN'S INTERPRETATIONS OF AERIAL VIEWS AS IT RELATES TO THEIR ABILITY TO UNDERSTAND THE EARTH AS SPHERICAL

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> I: Was this hard?
> M: A little bit.
> I: A little bit. Why was it hard?
> M: To see. ((waves hand over pictures)) [. . .]
> To explain it.
> I: To explain how you're seeing it?
> M: ((nods "yes"))
> --Interview with M, age 8, lines 48-55

> J: Hey, are you going to give me another hard question?
> --Interview with J, age 7, line 210

Learning to see what is placed in front of us is a skill that requires developmental readiness, an acceptable degree of background knowledge, and familiarity with the subject matter. In the absence of informed sight, our powers of interpretation are taxed, and the result can be dismissal, misunderstandings potentially leading to larger misconceptions, a search to make what we see fit in with existing schema (also fraught with the possibility of giving rise to misconceptions), and appeals to authority or unseen, incompletlely understood powers to account for what we can't make fit into place. All of these outcomes appeared in the data collected for this study, and although this presentation, preliminary in nature, will focus on young students' ability to interpret aerial views, each of these features becomes relevant as we think about ways of introducing young children to visual image data, as well as how we teach future teachers to do so.

Background

A persistent question in Earth Systems science education for young children (K-5) relates to children's ability to conceptualize the Earth as a sphere. In its review of students' conceptions of the nature of science and mathematics and of various topics within science, *Benchmarks for Science Literacy: Project 2061* (1993) speaks to several ideas students have associated with their understanding of the Earth. Among the first topics discussed are the shape of the Earth and explanations of astronomical phenomena (i.e., the day-night cycle, the phases of the moon, and the seasons). Citing the work of Nussbaum (1985), Sneider & Pulos (1983), and Vosniadou (1991), the authors conclude that, "Research suggests teaching the concepts of the spherical Earth, space, and gravity in close connections to each other." (*Project 2061*, 1993; p. 335) Reasons for doing so are that student ideas about the shape of the Earth are closely connected to their ideas about gravity. Students cannot accept that gravity is center-directed if they do not know the Earth is spherical, and they cannot believe in a spherical Earth without some understanding of gravity to explain to them why people "on the bottom" do not fall off. In addition, in order to understand the day-night cycle, the phases of the moon, and the seasons, *Benchmarks* concludes that "students should first master the idea of a spherical Earth, itself a challenging task." (p. 336) Although it is suggested that students cannot understand these basic concepts of the shape of the Earth, space and gravity until about fifth grade, questions still remain as to how and when children can understand and appreciate the implications of the Earth as a sphere.

Introduction to the Study

The current study originated in an effort to make space satellite data available to children in the K-4 classroom, and is the result of work sponsored by the National Aeronautics and Space Administration (NASA)-American Association for Engineering Education (ASEE) Summer Fellowship Program as a part of the Augmented Learning and Education for Renewable Teaching (ALERT) NASA-California State University (CSU) consortium. Recent work at NASA connected to the LaGESI (Laboratory for Global Environmental Science Information) Project has centered around making on-line, satellite data available to the general public and to schools across the nation. The LaGESI Project has among its goals to not only make such data available, but to make sure that they are in a form that is: (a) accessible via computer platforms that are typically used in schools and by the public, and that (b) the data be presented in a manner that is readily amenable to interpretation by an audience of users other than NASA and/or highly trained and specialized scientists. Specifically, scientists at Jet

Propulsion Laboratory (JPL) in Pasadena, California have been working on developing WebWinds, a web-based software that will make real-time space satellite data available to the public.

As this study was originally conceived, after an introduction to the software under construction, we would develop materials to accompany its use in the K-4 classroom (see NASA Summer Fellowship Proposal, Hawkins, 1999). The prospect of ready access to such data offers many possibilities for educational endeavors. After working with the software for a very short while, however, it became quite apparent that its effective use would rest heavily on the students' abilitiy to understand and interpret aerial views, three-dimensional views presented in two dimensions, and to go back and forth easily among these various views. In short, we had run headlong into some of the very issues associated with children grasping a conceptual understanding of the Earth as a sphere, as described in *Benchmarks for Science Literacy: Project 2061* (1993) and elsewhere in the literature (Driver, Guesne & Tiberghien, 1985; Nussbaum, 1985; Kretschmer, 1995; Osborne & Freyberg, 1985; Vosniadou, 1991). Before we could determine ways the data could be relevant and used most effectively in the learning process by young students, K-4, we needed to know more about their ability to interpret visual images, since it is clear that they will need to examine such visual data if they are to use software such as that provided by NASA. The visual data images that are available include, of course, aerial views of the Earth from the distance of satellites "looking on" the planet from afar, as well as data that can be superimposed on a two-dimensional map of the world. The questions this paper presents and examines are:

1. Are young children able to interpret aerial views, and if so at what age can they readily do so? If not, can they be taught to do so, and at what age?
2. Can incoming visual image data be used to help shape young students' view of the Earth as spherical?

Methods

In examining these questions, 15 semi-structured interviews were conducted and audio- and videotaped with a cross section of kindergarten, first, second, third and fourth grade students, ranging in age from 5 years, 1 month to 10 years, 3 months. In the group of fifteen students, there were 8 girls and 7 boys. The students were from one of two schools. One is a large (~1,200 students), public elementary school in the San Fernando Valley located in southern California, with a 92% Latino population, the other 8% divided fairly evenly among Anglo and Asian students. The other students come from a small, public elementary school (~400 students) near Pasadena, California with a fairly even distribution of African American (47%), Anglo (34%) and Latino (14%) children. In terms of socio-economic status (SES), all of the students ranged from low to middle SES. Twelve students' families were recent immigrants, having immigrated within the last 3-5 years. Spanish was the first language of all the children except three. The Spanish speaking children had the choice of conducting the interview in either Spanish or English, and 9 chose to speak in Spanish. After these interviews were transcribed in Spanish, they were translated into English. (For transcription conventions used, see Appendix A.) The length of the interviews varied from 23 minutes to 2 hours , 47 minutes, the shorter interviews from the younger children and, conversely, the longer ones from the older children.

The goal of the interviews was twofold. The first goal was to establish baseline data regarding children's abilities to interpret aerial views in general, and then as they relate to specific Earth Systems Science concepts; e.g., volcanoes seen "traditionally" from a distance and at the side, and then with varying views ranging from "close-ups", to a relatively close aerial view showing lava flow, to a shuttle picture showing several volcanoes, to a satellite view of the Pinatubo volcano where its smoke-filled debris is seen circling the globe, to a flat 2-dimensional map of the world showing the same ring of debris. Based on ideas expressed in child development regarding children's development of conception of space (Piaget & Inhelder, 1967; Vygotsky, 1978), we wanted to know when we were dealing more with developmental issues rather than conceptual issues in science. For this reason, we included visual data regarding aerial views in general, as well as those relating to more specific science concepts.

The second goal was to probe the children's thinking with respect to their observations, with the hope that this information would provide us with guidelines as to how we could approach young students' preparation for using the NASA data. Not only did we want to know why the children thought as they did, we also wanted to know if there was evidence of change due to the interaction about the visual data itself. In this sense, the interactions departed from those protocols established by others (Driver, Guesne & Tiberghien, 1985; Gentner, D. & Stevens, A., 1983; Nussbaum, 1985; Kretschmer, 1995; Osborne & Freyberg, 1985; Sneider, C. and Pulos, S., 1983; Vosniadou, 1991) engaged in the research on misconceptions in science, whereby emphasis is placed squarely on uncovering and describing the concepts the subjects have regarding a given topic. We presented the subjects with on-going logical problems as they developed during the interaction, provided "hints" about what they might be looking at, and often returned to earlier images to ask the subjects to intepret them in light of their more recently demonstrated understandings. In short, we wanted to see the teaching/learning effect of the interviews themselves. It should be noted, that we did not start out with this second goal in mind. Rather, we proceeded in this fashion only after a discussion of a pilot interview with a JPL WebWinds scientist (L. Ellson, personal communication, 1999), in which he pointed out that the very interview itself, accompanied by exposure to the data, seemed to have changed the subject's deeper understandings.

Results

For the purposes of this paper, the discussion is limited to two sets of pictures and the interviews that accompanied them: the general aerial views (pictures 1-4), and the series of pictures on volcanoes (pictures 5-11; see Table 1, below). After presenting an overall summary of the data in each category, specific examples of findings will be given, presenting data from the transcribed interviews for demonstration.

Children's ability to interpret aerial views in general.

All of the children were shown the four pictures in this category, and the general trend was that the five-, six-, and seven-year olds were unable, at least initially, to intepret the aerial views, whereas the eight-, nine-, and ten-year old children were. With the younger children, the interviews were often characterized by the interviewer trying to get them to see that there was a logical problem with what they were saying, and one of the hallmarks of success in this area was the pause length before the child's answer. Average pause lengths were determined for each child, and then compared with those that were either shorter or longer in the discourse. Almost without fail, the longer pauses occurred when the student was confronted with her own interpretation that she could see didn't make sense. The seven-year olds were perhaps the most interesting in this group, as they were those that demonstrated evidence of changing conceptions during the course of the interview. The five-year olds were often not even able to understand the issues involved, and although the six-year olds usually were able to understand the problems set forth, generally they were not able to modify their thinking to incorporate new information presented during the course of the interviews. By the third grade, most students showed evidence of an easy understanding of all four pictures in this section, and were more able to explain their reasoning. The only fourth grader included in the study was quite clear in her ability to explain both what she understood and did not understand; i.e., she seemed to know the root of her misunderstandings, and had become quite adept at the self-regulation of her thinking processes.

The five-year olds.

One of the most striking findings for the five-year olds was their inability to understand why their solutions would not work. None of them was able to give a complete interpretation of any the aerial views in the general section (pictures #2, #3, and #4), or make the connection between pictures #1 and #2. All but one were able to discuss parts of the aerial views accurately, especially pictures #3 and #4, but did not evidence any meta-awareness with respect to their conclusions. That is, they were not able to explain why they thought something to be a certain way, even if their interpretation was accurate. When confronted with lapses in logic,

Table 1

Numbered descriptions of the eleven pictures used during the interviews

Picture Number	Picture Description
Images, General in Nature	
#1	2 boys fishing off sandbags in front of a porch leading into a house; appears to be rural area
#2	aerial view, house in #1
#3	mountain climber looking down on a valley below him
#4	dog & man on hang glider overlooking Laguna Beach, CA
Images Related to Volcanoes	
#5	"green", relatively inactive volcano
#6	close-up of the mouth of a volcano with smoke pouring out
#7	bright orange lava flowing from a volcano; the volcano appears black and at first, the picture gives the impression of being taken at night; in the background, however, there is blue sky, (and possibly a body of water), showing that it was taken during daylight hours
#8	a truck "fleeing" the smoke of a volcano; the smoke is pouring out of a volcano and moving down a gradually sloped area, the truck right in front of it; unable to see the actual volcano
#9	a shuttle view of a volcanic island in the middle of the ocean; although the volcano takes up much of the island, it does not take up all of it
#10	"two worlds"; two separate pictures from space of the Earth, placed side by side; one is taken before the Mt. Pinatubo eruption and one is taken after it; the 2nd one shows the smoke from Mt. Pinatubo as it circles the Earth
#11	a 2-dimensional map showing the distribution of smoke from Mt. Pinatubo as it spread over the Earth

they sometimes would not even understand the problem at hand, and if they did, would deny the truth value of what the interviewer was saying, make an appeal to familiar sources of authority--

most often their parents--or "invent" a solution that was just as problematic as their original assertions.

One of the most interesting students in terms of his developmental level with respect to his conceptions about space, was a five-year old named Luis. He was the only student who did not realize the "aerial nature" of picture #4. Through a rather laborious series of turns to clarify meanings, the interviewer was able to get Luis to describe his understanding of the picture, and it became clear during data analysis that Luis was quite young developmentally in terms of his concept of space. Piaget and Inhelder (1967, pp. 3-43) argue that children first understand space topologically, when "visual and tactile-kinesthetic space are not yet related to one another" (p. 6). One of the elementary spatial relationships that seems to come into play in this example from Luis is that of "separation". According to Piaget & Inhelder (1967, p. 7), "two neighboring elements may be partly blended and confused." This seems to be the case when Luis (L), disregarding size relationships is not able to separate the hang glider and his dog from the beach below:

I: And the man, what is he doing? ((re. picture #4))
L: . . . (~3 sec)) He's at the beach.
I: He's at the beach? What's he doing at the beach? Is he flying over it?
L: ((shakes head "no"))
I: He's not flying?
L: ((shakes head "no"))
I: What is he doing?
L: He's on the sand. . . . ((~4 sec)) But he's a little bit in the water. He wants to go into the water.
I: He's a little bit in the water. Show me with your finger.
L: ((points to man's left arm, which is over the ocean))
I: Oh, so he's lying on the beach, but he's near . . . -near the edge and is putting his arm in the water?
L: ((nods "yes"))

When approached with how to reconcile the size of the man with respect to the ground and objects below him, Luis provides a creative solution that is just as fanciful as his first observation:

I: Well, do you see these little house over here?
L: ((nods "yes"))
I: Okay. Why--What are bigger--houses or people?
L: Houses.

I: Okay, houses. Then, why is this man so much bigger than these houses? . . . Is he bigger than the house--than this house, for example?
L: ((nods "yes"))
I: Do you think he can go in that house?
L: . . . ((~11 sec; shakes his head "no"))
I: Why not?
L: It's not his house, and other people are already in there.
I: Okay. ((laughs)) . . . But, I still don't get it, if this man had a friend who lived in one of those houses, how could he go in the house to visit him?
L: ((shrugs shoulders, "I don't know"))
I: You don't know?
L: ((Shakes head "no"))
I: It's a problem, huh? How come those houses are SO small?
L: . . . ((~14 sec; looks at I))
I: What do you think?
L: ((shrugs shoulders, "I don't know"))
I: Hmm?
L: . . . ((~ 14 sec)) [I KNOW--]
I: [Well--]
L: --really SMALL people live in those houses!
I: Really small people live in the houses?
L: ((nods "yes"))
I: Okay. So where do you think this man lives?
L: . . . ((~6 sec; shrugs shoulders, "I don't know"))
I: You don't know. Okay. Well, let's look at another picture.

Luis was not the only five-year old with creative, but fanciful solutions to the size/distance relationship. Jacqueline (Ja) and Antony (A) also offered their ideas:

I: But still, I don't understand how this man--as tall as he is--can go into such a small house.
Ja: . . . ((~6 sec)) It's because the DOOR is big.
I: The DOOR is big? [. . .] The door is bigger than the house?
Ja: ((nods "yes"))

I: Which are bigger--houses or people?
A: Houses.
I: Houses. But, in this picture, the man seems to be bigger than the houses. Why does it seem like that?
A: Well, the man is very big.
I: Good. If the man is flying, where is he? Is he on land or in the air?
A: He's in the air.
I: In the air. . . .--Looking towards what?
A: The water.
I: The water. Okay. And if he . . . were to go down to the earth ((points at the picture and moves finger to indicate the action of which she is speaking)), . . . and if he wanted to go into the little house here, . . . would he be able to?
A: ((nods "yes"))
I: But he's so big!
A: . . . ((~8 sec, during which time A stares at I))
I: How could he fit into such a small house?
A: . . . ((~4 sec)) small. By becoming small.
I: He's going to make himself smaller?

A: Yes.
I: A:H! Okay. . . . And, can you do that? . . . --Make yourself small?
A: ((shakes head "no"))
I: So then, how can this man do it?
A: . . . ((~11 sec)) He could lie down (and then he would fit).
I: A:H! If he lies down, he can do it.
A: ((nods "yes"))

Antony also gave a rather creative solution to the question as to the identity of the waves in picture #4. He begins by saying that he sees water in the picture, but cannot figure out what to do with the "white parts", how to reconcile them with his idea that the blue part is water. He then revises his original idea to say that there is no water in the picture, and proceeds to offer up another fantastic idea.

A: . . . ((~9 sec)) It's water. ((pointing to oean water surrounding the waves at the bottom of picture #4))
I: It's water?
A: ((nods "yes"))
I: Okay. . . . And, how do you know that it's water?
A: . . . Because it's blue.
I: It's blue?
A: ((nods "yes"))
I: Okay. And these white parts . . . --the white stripes ((pointing to the waves)), what are they?
A: . . . ((~6 sec)) It's from the snow.
I: And, the snow is in the water?
A: ((shakes head "no"))
I: So then, how can it be snow? . . . ((~4 sec; laughs)) It's a problem, right?
A: ((nods "yes"))
I: And, how are you going to solve it?
A: . . . ((~6 sec)) It's light.
I: Hm?
A: It's light.
I: It's light?
A: ((nods "yes"))
I: And, where does the light come from?
A: . . . ((~13 sec)) From the ground.
I: From the ground?
A: ((nods "yes"))
I: . . . ((~9 sec)) Okay. And, what else do you see?

On another note, Jacqueline offered the most appeals to authority of all the children, and they were different from those offered by older children in that her 'sources" did not have to be credible to anyone but herself. In the first excerpt, she is describing what picture would result if the mountaineer in picture #3 were to take one with his camera.

I: This then--What would come out? Show me with, with your finger.
Ja: Um, . . . the ground and this.
I: Ah-ha, the ground and this. Then, --And the person that took the picture of HIM . . . where was he? . . . ((~6 sec)) I-Is it the same person that took this picture?
Ja: ((nods "yes"))
I: He took this picture also?
Ja: . . . ((~6 sec; nods "yes"))
I: How?--Why do you think that?
Ja: Um, . . . Because my daddy explained it to me--he told me it.
I: Your daddy told you it? When did he tell you it?
Ja: In the night.
I: In the night. Okay. ((laughs))

In the second excerpt, she is defending her view of the person who is closest to the ground, looking at pictures #3 and #4:

I: Now, ((sighs)) . . . I want to know . . . um, Who is clos--who is closer to the ground--this man ((#3; points)), or this man ((#4; points))?
Ja: The one closest to the ground is: . . . THIS man! ((points; #3))
I: And, how do you know that? . . . How do you know? Tell me!
Ja: Because . . . because my daddy told me it.
I: Your daddy told you that, too! Woh! What a daddy you have! How smart he is!

The seven-year olds

As mentioned earlier, the seven-year olds were quite interesting in that, although they did not completely understand the aerial views or the relationship between pictures #1 and #2 at the beginning of the interview, they were able to focus and engage with the tasks, recognizing problems where the younger students could not. This engagement served them well in the end, as most of them produced some evidence of new understandings during the course of the interview. In addition, as they grew in their ability to interpret the views more accurately, they began to self-regulate, not needing the interviewer's prompts so extensively to trouble shoot their ideas. Jack offers some very clear examples of both of these features, i.e., growing in his understanding and ability to interpret the various views, and in his ability to self-regulate his own thinking.

In the first two excerpts, we see Jack (J) trying to explain where the person who took the photograph in picture #2 must have been in order for it to have come out as it did. By the end of the second attempt, he is aware of the problem--note pause length--and realizes that he does not understand where the picture was taken.

Attempt #1

I: Where would they be standing? . . .
J: They--
I: --To take the picture ((re. picture #2))?
J: Probably . . . on their walksi--their side walk.
I: On the sidewalk?
J: Uh-hm. ((yes))
I: Okay. But, can you see the roof from the sidewalk near your house?
J: No.
I: So, will that work?
J: No. ((sighs))

Attempt #2

I: So where was the per--person who took this picture ((picture #2))?
J: In the river!
I: In the river, too?
J: Uh-huh! ((yes))
I: So how would you get the top of the roof if you're standing in the river?
J: O:h, O:h ! ((laughing while talking, but showing exasperation))
I: ((laughs)) Isn't that a problem?
J: Uh-huh. ((yes))
I: Can you see the top of the roof . . . ((~2 sec)) if you're just standing out on the sidewalk or something?
J: Uh-uh. ((no))
I: So how'd they get that picture?
J: Probably they were standing on the, um . . . um . . . ((~3 sec)) in the river and then they just took the picture!
I: But how did they get the picture of the top of the roof?
J: . . . ((~3 sec)) O:h, now I see what you're saying! Um . . . ((~11 sec)) mm . . .
I: You want me to go to the next picture?
J: Yeah.

Related to this is Jack's explorations of alternatives when he does not understand that the houses in pictures #1 and #2 are actually different views of the same house. His offering is definitely more plausible than those of the five-year olds, even though it is still incorrect. In this excerpt, the interviewer presents Jack with picture #1 and asks him to compare it to picture #2:

I: Okay. Now I'm gonna show you another picture. . . . ((~2 sec)) Okay, let me show the camera first. . . . That's that picture. . . . Okay, and I'm gonna put it next to this one. . . . ((~3 sec)) NOW what d'ya think?
J: . . . Umm--
I: Does that give you any clue?
J: Cou-Could you turn it like this?
I: Yeah, you can turn it anyway you want.
J: Alright. . . . ((~4 sec)) Do I say what I see?
I: Yeah. Do you think it's . . . connected to this picture at all?
J: . . . ((~3 sec)) Um, let's see. . . . I don't think it's connected. [. . .]

I: Okay. Okay. What if I were to tell you that this picture . . . is a picture of this house?
J: . . . (~ 2 sec)) I--I don't see what you're saying.
I: Where would a person have to be to take this picture?
J: . . . um . . . Probably . . . on the, um, . . . --Wait. Are they like neighbors?
I: . . . Nah, I think that's the same HOUSE!

Several minutes later in the interaction, after Jack and the interviewer have discussed pictures #3 and #4 at great length, Jack is able to extend what he has become aware of during this time to the earlier picture, picture #2. Once he is able to do so, he laughs causing the interviewer to join in in his excitement at figuring it out. Also note how easily Jack is able to use the size-distance relationship to defend his ideas about who was higher up, the person in picture #3 or in #4.

I: Now who do you think is higher up? . . . ((~1.5 sec)) This guy from here, ((points to picture of man on mountain)), or this guy from here? ((points to picture of man on hang glider))
J: This guy. ((points to man on mountain))
I: Why do you think that?
J: Because this part looks bigger--
I: Uh-huh. ((yes))
J: --And this part looks smaller.
I: Ah-ha:! VERY . . . good . . . thinking!
J: O:h! ((rising-falling intonation; emabrrassment & pride at the same time))
I: I . . . must. . . say! ((laughs)) Now, I'm gonna go back to this one.
J: Not this one agai:n:! ((whiny))
I: Now, just thinking of that, how could you get that picture? . . . ((~4 sec)) Where would the person have to be?
J: Probably . . . ((~5 sec)) UP! [((laughs))]
I: [((laughs)) Up in the air, not standing in the lake, huh? ((laughs))]
J: Right! ((laughing while talking))
I: Why would he have to be up in the air?
J: Because you can't, um . . . --How would you be able to see the ROOF?
I: Very good! Now, what about THIS one? Where could he be?
J: They could be in the lake.
I: They could be in the lake, standing this way, looking at it.
J: Yeah!

The last excerpt lets us witness Jack as he begins to develop his own strategies, almost as if in anticipation of the interviewer's questions. He brings to bear his "new thoughts" about the logical necessities for his claims about what would be possible given the constraints of the situation for picture #2.

I: Okay, good. . . . Now, . . . could it be that this is all lake around here? . . . ((~2 sec)) --Or all water around here?

J: I don't think it could be, because how could, um, . . . this go in the picture like that? ((points to truck)) How--
I: --How could the truck be there?
J: Yeah.
I: That's a good question.

The ten-year old

The ten-year old, Whitney, was very interesting in that she flew through the first four tasks with ease, often adding without prompting her own thoughts about why or why not something had to be a certain way. At times this served as encouragement to the interviewer to probe even deeper, and Whitney was able to hold her own. Actually, this held true for the entire interview, the only place where she really stumbled at all being on the last picture of the two sets, #11. Below is Whitney's (W) reaction upon seeing picture #2 for the first time:

I: Well, just tell me what you see ((picture #2; aerial view of house in #1)), first of all.
W: Well, I see, uhm, . . . ((~4 sec)) uhm, probably, maybe another case of a flood and a house. . . . Well, probably not a flood because . . . the CAR'S right there . . . and up, so you could see it very well. [. . . Break in transcription . . .]
W: And, uhm, . . . it ((picture #2))looks kinda like that--this house, right here ((points to picture #1; boys fishing off of sandbags in front of the house)). . . .
[--Where the boys are at.]
I: [Uh-hm. ((yes))] What makes you say that?
W: Well, probably because of the sandbags and, like, . . . the . . . wall, . . . like over here ((points to picture #2)), the --it kinda . . . it, like the . . . parts right here. ((points to picture #1)) . . . [-And right there-- ((points to #2))]
I: [Oh, okay.]
W: --it kinda has a similarity, uhm . . . ((~4 sec))
I: Now, where would the photographer be who was taking . . . this picture?
W: Probably in an airplane, or, like, on a--maybe a, uhm . . . uhm . . . a, like a--higher, like a rock , like a . . . big . . . rock-- ((gestures with hand hovering over picture))
I: You mean higher--?
W: Yeah, a higher surface.
I: Higher surface than what? The house?
W: Yeah, than the--but probably an airplane.
I: Why would you say that?
W: Why an airplane?
I: Yeah. Why couldn't . . . he be down on the ground? . . . --Or she be down on the ground?
W: Because it's--it has the roof view, and . . . like the up--like ((holds hand over picture with fingers pointing down towards it)) --it's going, like, . . . down.
I: Oh, so it's looking down . . . on top of the house?
W: Yeah.
I: Okay. And what about THAT one ((points to picture #1))? --Where would the photographer be?

> W: Like, . . . right in . . . front of the house, like . . . ((picks up picture #1 and holds it vertically while placing her other hand in front of it)) probably like right . . . here. ((indicates location in front of the picture with free hand))

In summary, not surprisingly, the older the children were, the easier the task was. The seven-year olds seemed to benefit from the interaction in the sense that it provided the scaffolding that pulled them through what Vygotsky might identify as their "zone of proximal develoment" (1978, pp. 84-91) with respect to their growing spatial concepts. There is evidence to support that they went from not understanding to constructing meaning via the interaction which was both cognitively and socially demanding for them.

The volcanic images

The volcanic images that were presented to the children (pictures #5-#11; see Table 1) required them to go beyond the first set of images in that they asked them to move from images of landforms from the point of view of somone on the surface of the Earth to satellite images from the point of view of someone in space looking back at the Earth, or a portion of the Earth. In addition, the last picture asks them to interpret a two-dimensional view of the smoke debris that circled the globe after the eruption of Mt. Pinatubo, with a silhouette map of the continents imposed on top. This is to say, that the students now had to convert aerial, satelite view information to a more conventional presentation, and make the connection between them overt. Interestingy, only one student was able to do this--Geraldo, an eight-year old in third grade.

Likewise, it might be that the more students knew about volcanoes, the more successful they were in interpreting the images. Most of the youngest children had trouble with these images right from the start. Although most seemed to have at least a minimal knowledge of what a volcano is, the extent and source of their knowledge was not always clear. This was particularly true with the five-year olds, and it may be that a lack of "real world knowledge" played as great a role here as did the students' ability to manipulate the various perspectives of the different images. This disadvantage was especially noticeable when the images presented the more standard depictions of volcanoes, since those would be the ones most likely for them to be able to interpret, and when they weren't able to do so, one wonders whether their background knowledge was sufficient.

The five- to seven-year olds

Once again, with the exception of one eight-year old, there seemed to be a fairly strong line of demarcation between the students seven and younger and those eight and older. It was difficult to know how much of this is attributable to lack of background knowledge on the part of the younger students, how much is attributable to their lower developmental level, and how much of it is an interaction of both background knowledge and development.

Three of the younger students provide insight as to the role of background knowledge: Jacqueline, Antony, and Jack. According to self-report, Jacqueline's baseline knowledge seems to have come from cartoons:

I: [. . .] Do you know what a volcano is?
Ja: . . . ((~4 sec)) Um, . . .
I: Well, have you seen a picture . . . like this one? ((#5))
Ja: Um, In the cartoons.
I: What?
Ja: In the cartoons.
I: In cartoons. Okay.

Both Jack and Antony used their background exposure to interpret picture #7, the picture showing orange lava flowing out of a dark, black volcano, to say that it was showing the inside of the volcano. Jack is very clear about this, and argues his point with the interviewer, who at first does not understand what he is saying:

J: Maybe they looked up, . . . and so then you only see--saw this part, where they took it.
I: But how could they see this part if they were at the bottom? Suppose the bottom was down here--
J: No. Like-- . . . Here. . . . ((~3 sec)) Say . . . this . . . whole part is it. And I was at the--right at the bottom. And they just looked up and they took it--the picture.
I: Okay. . . . ['kay.]
J: [They jus--]
I: . . . Now--
J: Oh is this in the inside part of it? . . . Oh; it's in the inside.
I: No, it's not really the inside!
J: Yes it is, because . . . ((~4 sec)) --Lookit. . . . It's, um--this is all coming down (the lava).
I: It's coming DOWN, down what?
J: I mean it's coming U:P!

I: ((laughs)) Oh, I see! You're saying that this is coming up and this is the explosion!
J: Uh-hm. ((yes))
I: See, what I:--I"ll tell you what it is. This is the explosion and this is the stuff coming down. --Out of it. . . . ((~6 sec)) Do you think that could be?
J: I don't think it could be!
I: Okay.
J: Because nothing comes down-- [. . .] Yeah, see . . . --all this dark black stuff . . . is the, um, volcano!
I: The outside of the volcano, or the inside?
J: The inside.
I: Okay. . . .

Antony's description is not as immediately obvious as Jack's, but it is clear that he also must be thinking he is seeing the inside of a volcano. In the excerpt that follows, he is very definite that the lava is flowing up from the bottom of the volcano:

I: In this one. Okay. Now I'm going to show you THIS picture. . . . OOH! And, this, what is it?
A: Fire. ((as in coal embers glowing))
I: Hm?
A: Fire.
I: Fire. Okay. And where is it coming from?
A: . . . From the bottom.
I: From the bottom. So then, . . . where is--There's a volcano here. Do you see the volcano?
A: ((nodds "yes"))
I: Where is the mouth of the volcano?
A: . . . ((~5 sec)) Below. ((pointing while speaking))
I: Below. Like, where?
A: . . . XXX
I: Here. ((points to the bottom of the volcano))
A: ((nods "yes"))
I: So, how does . . . the fire go? Does it go up or down?
A: Up.
I: Up. So then, the mouth is down here?
A: ((nods "yes"))

The question immediately arises as to why both boys thought that the lava was flowing up. Jack's thought that he was looking at the inside of a volcano might be helpful. Without having the benefit of having asked the boys directly, a reason that seems likely at this point is that picture #7 closely resembles drawings of the inside of a volcano that often appear in science book explanations of how volcanoes happen. This would make sense in that it could be the boys' main exposure to volcanoes.

Finally, we have some of the same appeals to authority from the younger children, and as with the general section on aerial views, the younger the child, the less credible the support.

In the next excerpt, Jacqueline introduces us to a new source, this time in defense of her ideas about which photographer was closer to the volcano--the one in picture #5 or the one in picture #6, where picture #5 is taken from a distance, and #6 is a close-up of the mouth of a volcano during eruption.

Ja: WHA:T? ((in loud voice, with exagerration))
I: A person took this picture, right?
Ja: ((nods "yes"))
I: And another person took this picture. . . . Okay?
Ja: ((nods "yes"))
I: So, what I want to know is, who was closer to the volcano, . . . when they took the picture?
Ja: Uh-hm ((yes))--
I: --The person that took THIS one, or . . . the person that took THIS one?
Ja: The person too:k . . . THIS one.
I: This one. . . . How do you know?
Ja: . . . ((~4 sec)) Because . . . ((~3 sec))
I: Don't tell me that your daddy told you!
Ja: I knew it all by myself!
I: What?--You know it all by yourself? Yes, but, how?
Ja: Because I--she told me my: . . . ((~3 sec)) --my AUNT!
I: Your AUNT? Now the aunt! Okay. ((laughs))

Finally, Jacqueline decides that, in the absence of her ability to produce an acceptable authority, she needs to strongly deny what she clearly sees. It is difficult to know exactly why she does so; i.e., is it a case of "stubborness", is it because she cannot explain what she wants to say, or is it because she is engaging in a kind of interactive play with the interviewer? Her task is to say what she thinks is coming out of the mouth of a volcano, which is a rather tame stream of smoke.

I: [. . .] Um, . . . And this ((points to smoke coming out of volcano)), what is it? . . . [--That's]
Ja: [It's--]
I: --coming out of the mountain.
Ja: Coming out is: . . . ((~4 sec)) fire.
I: Fire's coming out?
Ja: ((nods "yes"))
I: Okay. This is fire?
Ja: ((nods "yes"))
I: Okay. . . . ((~3 sec)) And, how do you know that it's fire?
Ja: Because my ma- . . . my sister told me it also.
I: But I want to know how, LOOKING at this, do you know that it's fire.
Ja: . . . ((~5 sec)) Ma, . . . --(Because I've seen it and I know it.)
I: By the color? . . . What color is it?
Ja: It's . . . white.

I: It's white. And, fire is white? . . . ((~3 sec)) What color is fire?
Ja: Um: . . . ((~3 sec))
I: More like red? . . . Or orange?
Ja: Red.
I: Okay. So, it can't be fire.
Ja: ((nods "yes"))
I: No it isn't! ((laughs hard))
Ja: Yes, it is.
I: It's smoke.
Ja: NO!
I: No?
Ja: ((shakes head "no"))
I: You don't think so? Okay.

Jack also calls upon authority, but seems to have learned that there are more "acceptable" authorities than family members. In this first example, he calls on those whom he believes to be unquestionable authorities as he tries to solve the dilemma about the "inside view" of the volcano. His authorities involve scientists--"who know more than the rest of us about these things", Jack seems to assume--, and their "all-powerful" tool, the computer. As Jack uses these authorities, he seems to assign a degree of magic to them that he assumes that we all assign to them. The effect of the interviewer's reiteration that the photograph is "real" lends support to this idea.

J: Wait. [Actually--]
I: [So, how much--] How did they cut this volcano in half? . . . ((~2 sec)) -- So you could see the inside?
J: . . . ((~3 sec)) I--
I: Why can't you see the inside of this one? ((re. picture #5))
J: . . . ((~2 sec)) Probably . . . ((~2 sec)) um, . . . ((~2 sec)) SCIENCE people had to take this one ((#7)) off of a computer.
I: O:h! So they were the ones who cut it in half?
J: Uh-huh. ((yes))
I: Well, what if I told you it was a real picture, and somebody took it?
J: Wait. Is it--Is this a real picture?
I: It's a real picture. . . . ((~3 sec)) So it wasn't just off the computer. It's like somebody took it with a--
J: No, you know how. like--
I: Somebody took it with a camera. . . . ((~4 sec)) [Like--]
J: [No--]
I: --how you took those pictures yesterday . . . at Disneyland? Somebody took those pictures with a camera.
J: . . . ((~5 sec)) Mm . . . ((~6 sec))
I: Wanna let that one go for a minute?
J: ((nod "yes"))

By the end of this excerpt, Jack is aware that he has a problem with his original statement that picture #7 presents the image of the inside of a volcano, but in the next example, it is as if he already knows he's in trouble before he gets started. He is looking at picture #11, a 2-dimensional map showing the distribution of smoke from Mt. Pinatubo as it spread over the Earth. The interviewer has just asked him a question about what it is that he sees, and he calls upon a revered source of authoritative information.

I: They all have SOMEthing to do with volcanoes. . . . But see,here, we didn't see the volcano--we just saw the smoke from the volcano, right? Going around the earth. . . . Right?
J: Uh-hm. ((yes, softly))
I: So what could that yellow stuff be? That yellow and white stuff?
J: I wish I had a book with me to show me what that stuff is.
I: ((laughs)) I'll tell you if you want me to, but I [want you to--]
J: [Alright,] tell me!

In addition to the book, it is also clear that Jack considers the interviewer to be an authority. In the absence of a book, she will be a reliable source of information. This raises the question of how and when we come to consider whom and what to be authorities. Was it because the interviewer is older than Jack that she is the authority? Is it because she is the one with the pictures? Is it because she has questioned some of his other responses?

The older students

Of the older students, perhaps the most interesting pictures for discussion were the last two: #10 and #11. For #10, although the students were able to identify the picture as having two images of the Earth taken from afar, and that one had "green stuff" circling around it, they were not able to say what the "green stuff" was. This was true even after they had been told that one picture of the Earth was before a "huge" volcanic eruption, and that the other was taken after it. Their credulity was taxed when they heard exactly what it was, although none chose to question further. Below, is an excerpt from Whitney, where she is readily able to identify the view in picture #10, but is unable to identify the trail of smoke:

W: It ((picture #10)) doesn't look like volcanoes. . . . ((~3 sec)) [--A volcano.]
I [Okay.] What . . . if I just showed you that ((covers up post-Pinatubo photo of Earth, leaving pre-Pinatubo photo to look at)), and I didn't say anything about volcanoes?
W: I'd say it was, like, . . . uhm, a--from space . . . a view of the Earth.

I: A view of the earth from space. Okay. you're right. . . . This ((points to left side of picture#10, the pre-Pinatubo photo)) is a view of Earth . . . from space beFORE . . . a volcano eru--a volcanic eruption, . . . and this ((points to right side of picture #10, the post-Pinatubo photo)) was AFTER the volcanic eruption. . . . Pinatubo . . . was the volcano. . . . So, do you see any difference in the two?
W: Yeah!
I: What's different?
W: ((points to #10, post-Pinatubo photo)) It almost looks like the land is, like, BLENDING together.
I: The land blends together on this one? ((points to #10, post-Pinatubo photo))
W: Yeah, kind of! . . . ((~3 sec)) Yeah!
I: Now, on this one ((points to #10, post-Pinatubo photo)), I see some stuff along here ((points to smoke from the volcano))--
W: Yeah.
I: Do you see that on this one? ((points to #10, pre-Pinatubo photo))
W: No!
I: So, what do you think that is? ((re. the smoke, #10, post-Pinatubo photo))
W: . . . [I don't know!]
I: [Did the Earth] get BIGGER?
W: No: ((falling intonation)) . . . ((~4 sec)) No.
I: So what could that be?
W: I don't know!

None of the children knew what to make of picture #11, although Whitney and Geraldo came closest; it was as if they had all the parts but could not put them together. The following excerpt shows Whitney's struggle to interpret the picture. At first she thinks she does not know anything about the picture, but later is able to work out some of the information following the interviewer's questions.

I: Okay. So, what's THAT? ((shows picture #11))
W: . . . ((~12 sec)) I have no idea! ((laughs)) It looks like, uhm, --I don't know!
I: Anything you recongize at all?
W: Yeah!
I: [What?]
W: [It looks like] . . . --Well, it almost looks like that's South America and North America. Maybe, like, the XXX, like . . . Africa.
I: Uh-hm. ((yes))
W: Europe and s-- and . . .
I: Australia?
W: Australia.
I: And Asia over here. ((points on map))
W: Yeah.
I: You'd be right about that!
W: But--yeah, but I don't know what that gold-- . . .
I: Now remember, it has something to do with a volcano.
W: Maybe . . . ((~4 sec)) No, I don't know.

The interviewer and Whitney go on to discuss what the connection between the map in picture #11 and the two satellite views of the Earth in picture #10. Although she is able to talk about each picture separately, she has difficulty putting them together. In the end, she remains uncertain.

I: So, where did they take this picture from? ((re. picture #11))
W: . . . ((~5 sec; shrugs shoulders--"I don't know"))
I: ((laughs))
W: Possibly . . . space, I don't know.
I: Now, if they were to take a picture of the world from space--because, see, like, here's--we've got North America-- ((pointing to continent/s in picture #11, and then in #10, for camparison purposes))
W: No, it couldn't have been space, because . . . ((~5 sec))--No, I don't know! . . . ((~3 sec))
I: Huh? . . . ((~2 sec)) This one ((re. picture #10)) you think is from space?
W: Yeah.
I: Now--And why do you think this one ((re. picture #10)) is from space?
W: Because! I mean . . . you can't, like, . . . go . . . out in your yard and get a full picture of . . . Earth like that.
I: Okay. Okay, so we know that that's out in space. ((pointing to picture #10)) Now, this one ((pointing to picture #11)) . . . ((~4 sec))
W: If it's from space, it'd be like this. ((points to picture #10))
I: It would look like this. ((pointing to picture #10)) So we know it's not from space. So, WHAT IS it?
W: . . . ((~7 sec)) Actually, I have no clue! ((laughs))
I: Do you think it's REAL? ((re. picture #11))
W: What do you mean?
I: Do you think it's a real picture? . . . ((~3 sec)) --I mean, a photograph. ((re. picture #11)
W: . . . ((~3 sec)) No. I- I- I- --well, may--maybe.
I: . . . But if you took a real photograph, what would it have to look like? --Of the world.
W: . . . ((~4 sec)) Like this. ((points to picture #10))
I: Right. So, it couldn't be [that-- ((points to picture #11))]
W: [So, it's] probably, like, on a computer or something.
I: Okay. So, . . . what-what else have you seen--How did you know those were the continents?
W: Familiar from my school.
I: From school. And when you look at those, your teacher tells you and teaches you the names of them in school, what are you looking at? . . .
W: Like, the . . . SHAPE of the land. What I look at is, like, the shape of the land and, like, where it's located on a map.
I: Okay, so you're looking at a map.
W: Yeah.
I: So do you think this ((pointing to picture #11)) is like some kind of map?
W: Probably, like off of a computer, maybe.

Geraldo (G), on the other hand, knows immediately how to make the connection between the 2-dimensional map of the world in picture #11 and the satellite views of the Earth in picture #10. He demonstrates that he is able to make this connection by telling the interviewer explicitly how to go from the flat map to the round globe.

I: Now, here's another question--Is the Earth round or flat?
G: It's round.
I: Okay. If it's round, . . . ((~5 sec)) and this is the Earth ((points to picture #10, view of Earth from space--pre- and post-Pinatubo photo)) , how can this be there Earth? This is flat. ((points to picture #11, 2-dimensional map of the world showing the distribution of smoke from Mt. Pinatubo))
G: Probably 'cuz, that's ((pointing to picture #11)) a map, . . . and that's ((pointing to picture #10)) the Earth.
I: Well, how--how did they get the MAP . . . of the Earth? [. . .]
I: How do you get from something that's round to a flat paper? [. . .]
I: Okay. But how does that make the world-- . . . How come it's FLAT . . . if the world is round? The map is flat, . . . and we say it's a map of the world.
G: Because, . . . if you want it round, you . . . have to put it on a ball. ((uses hands to simulate around shape, a ball)) . . . A big ball.
I: How would you put this on a ball? ((pointing to picture #11))
G: . . . uhm, . . . (Taking it and passing it around the ball) , , , and paste it.
I: So, like how? Suppose my fist . . . is a ball. How would you paste it? ((I hands G picture #11 and puts her hand into a fist and extends it outward, in front of G))
G: Like that. ((G wraps picture #11 around I's fist))
I: Oh, I see. So, actually, this map goes around like that? ((forms a cylinder with picture #11))
G: And on the bottom.
I: And the bottom, and the top, too. [Okay. Good!]
G: [((nods; "yes"))]

Geraldo clearly understands the two images, and demonstrates decisively that he can go back and forth between both images--at least insofar as understanding that the map was a flat version of the globe. Without help, however, he was still unable to understand the gold strip as showing the path the smoke and debris from Mt. Pinatubo took as it spread around the Earth. This is somewhat surprising, given the sophistication that he demonstrated with respect to his facility for translating the map and the globe.

In summary, both the younger children and the older children demonstrated some ability with the volcanic images, although the younger children's descriptions were much more limited. Again, the seven-year olds seemed to benefit the most from the interaction, and there seemed to be times when they were directly using what they had learned in the earlier general sequence on aerial views. This became especially apparent with the views of the Earth from space.

When the students did not know what to make of an image, and when they were confronted with the lack of logic in one of their observations, they did call on authorities to "rescue" them. The older the children, the more savvy they appeared to be about what "counts" as a more acceptable authority--i.e., as one upon which they could rely.

Conclusions

One longer term goal of this project is to use the results of the interview data to develop ways of access to the NASA satellite data in such a way that they would be amenable to helping teachers shape young students' concept of the Earth as spherical. A second longer term goal is to pilot the product of this effort, continuing the study of how the satellite data might help children develop a concept of the Earth as a sphere in space from very early on, avoiding misconceptions that often linger on into adulthood.. The images that the NASA satellite data offer provide us with a view of the Earth that has not really been obtainable until now, i.e., the possibility to see ourselves from a distance. This possibility, in turn, offers another, which is that of providing an experience of this view to students, in essence giving them a "discrepant experience" of the Earth as "round, but with flat places where I live." The first order of business, however, is to find out more about children's ability to interpret different views of the same phenomena.

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Appendix A: Transcription Conventions

Symbol	Meaning	Example
. . .	untimed pause, < 2 seconds into, uhm . . . second grade.	In September, I'm heading
. . . ((~ __ sec)) seconds	approximation, timed pauses, come from? Earth.	I: And where does the light >2 A: . . . ((~13 sec)) From the
uhm	filler	I THINK they're, uhm . . .
capital letters	stress	I THINK they're, uhm . . .
vowel :/::	elongated sound; approximate consonant consonant:/:: length of elongation indicated by number of colons	• A::nd, . . . what grade are you going into? • Som:eone left it there, I guess.
XXX	garbled utterance	What XXX?
( )	questionable trancsription utterance	(Taking it and passing it of around the ball)
(( ))	commentary, gloss	I think it's on TOP! ((laughs while talking))
((= ?))	question gloss	((= re. picture #4?))
?	rising intonation in a question	Because you could see . . . ((~15 sec)) where the lava comes out?
!	to show excitement (a combination of volume stress & intonation)	I: Where would the person have to be? J: Probably . . . ((~5 sec)) UP!
- / --	interruption, hanging sentence, intonation or abrupt change of thought	• It's the m-mountain • How does that-- How-- What--what part is THIS . . . --of the volcano
[ ] [ ]	overlap (more than one speaker at a time)	I: [All of 'em do.] J: [NO:--O:! ((laughs))]

GLEANINGS FROM IDENTICAL TWINS STUDYING SCIENCE

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Gleanings from Identical Twins Studying Science

This paper explains and summarizes some of the results of a study that investigated the ways in which monozygotic (identical) and dizygotic (fraternal) twins learn. It specifically investigated their individual learning style elements according to the Dunn & Dunn (1977, 1996) model. The research consisted of administering the Dunn, Dunn, & Price (1980) *Learning Style Inventory* along with a series of interviews, document collections, and grounded surveys. What is discussed here are the themes, unique needs, and characteristics monozygotic twins expressed in the interview process. The qualitative data collected from the interviews was most illuminating. The data are classified into five principle themes that are relevant to teachers and teacher education programs.

Previous Twin Research

Many of the studies involving twins have indicated they share various common traits, aptitudes, and academic achievement records (Bouchard, Lykken, McGue, Segal, & Tellgen, 1990; Wilson, 1986; Segal 1985). Some studies such as the Bouchard Minnesota Twin study compared the psychological and intelligence quotients of identical twins reared apart and found many striking similarities (Wilson, 1983). Some of these similarities were attributed to the effect of heredity. However, few studies have evaluated how twins learn (Wright, 1997). Fewer studies have focused on the qualitative aspects and the relationship between twinship and learning. The purpose of this research was to qualitatively look at the unique experiences identical twins have had in their formal and informal learning.

This study involved four pairs of identical twins who had pursued studies preparing them for science related professions. Each individual was interviewed on three separate occasions and was given the Dunn, Dunn, & Price *Learning Style Inventory*. Three pilot studies prepared the researcher and refined the methodology for this study. Grounded surveys, document collection, and member checks were also an important part of collecting, analyzing, and clarifying research data.

The participants in this study were of adult age and had completed secondary school, thus having the opportunity to reflect on at least 12 years of their formal and informal learning experiences. Each pair of twins was selected based in part on their decision to pursue science-related professions, along with a history of strong academic achievement. Three of the four pairs of twins were male, one pair was female.

The data, once collected, transcribed, coded, and analyzed, revealed many insightful vignettes. The twin siblings revealed subtle but significant differences in how they learn. For example, several of the participants in this study discussed specific study strategies, such as the reliance of tactual (writing) techniques or the use of unique sleep-study cycles. Such strategies were not shared by their sibling twin. The stories each individual told often revealed unique challenges that being a twin posed in learning situations.

Five Themes and Specific Examples

Five themes emerged across the four sets of twins. These themes are discussed in general and followed by some of the vignettes and experiences shared by the twins in the interviews.

The Impact of Non-formal / Informal Learning Experiences

The influence and importance of participating in non-formal / informal learning experiences was cited as an important part of developing an interest in science. However, even though a set of twins may have been involved in an experience, such as scouting, each had decided to pursue different scientific disciplines and continued to explore different interests.

This theme surfaced frequently as many individuals spoke of early learning experiences they had beyond their formal school experiences. They frequently spoke of individuals who taught them how to satisfy their curiosity for learning. Dan and Mike spoke of the tragic but significant event in their life when their father was involved in a serious automobile accident. They became involved as adolescents in learning information relating to their father's condition and his treatments. Their informal education included many conversations with the physicians and nurses attending their father, as well as reading and researching medical literature to help them and their mother understand/make medical decisions. It was during these informal learning experiences that Mike and Dan first began thinking of the medical profession as a possible career. Both agreed that these informal and the on-going medical issues with their father had a significant role in their decisions to study medicine.

Other significant informal learning experiences that both Mike and Dan shared were educational family vacations with their parents. They recalled visiting historical sites, reading and using maps, and learning about places they visited. Such experiences, they agreed, had given them a genuine interest and love of learning, which contributed to their academic success. They continue to use skills and enjoy such learning experiences as adults. Mike and Dan reported that they continue to enjoy map reading and educational travel today.

John and Jeff, a set of identical twins studying nursing (RN) as a career, reported another example of a significant informal learning experience. Their mother was employed at a large metropolitan hospital as a receptionist. As children they would often accompany her to the hospital and investigate, ask questions, and explore the surroundings. They were also fascinated and attentive to the stories their mother would relate at home regarding medical emergencies or hospital treatments. They spoke favorably of such experiences and how they figured into their decision to study to become registered nurses. They also had plans of using their medical knowledge as paramedics as well.

At one point Jeff was hospitalized and both he and John experienced the care and work of registered nurses. This too, gave them insight into hospital work. It was one of many informal hospital learning experiences for them.

Jill and Ann spoke of the significance their parents had, especially their father, in helping them with homework and maintaining high academic expectations. Ann recalled the times their father would give detailed explanations of how to repair mechanical devices. Their father's engineering background yielded information and curiosity about how objects work. This was shared with his daughters who expressed a sense of that curiosity in their personal and career pursuits.

In the case of Carl and Jay, it was the informal education they received from scouting that helped motivate them to become active and enthusiastic learners. Their experiences with a very knowledgeable and patient scoutmaster helped them decide to study science in college. Their parents too encouraged their continual learning. Carl and Jay recalled the camping and traveling experiences they had in their youth, and how such experiences contributed to an appreciation and respect for the natural world, as well as a continued interest in science.

Competition Among Twins

Each twin pair repeatedly discussed the role of competition in their learning experiences. Although the competition was viewed favorably by three of the four pairs of twins, the expectation to compete was frequently reported. Their family, peers, and teachers often projected such an expectation toward the twins, whether intentional or not.

For Ann and Jill the competition was unique and pivotal to their academic pursuits. Early in elementary school Jill deliberately decided to excel in certain subjects that her twin sister did not. She also recalled being compared to her twin sibling by her mother. Jill explains:

> Yeah, I think probably a little bit… (We were often compared and competed.) I don't know if it was so much from our perspective, as from my parents, at least my mother's. I remember being compared a lot, and like Ann getting into National Honor Society before I did or getting some honor or something. That being kind of a big deal, kind of pressure on me to accomplish that. I think in a way it was intended to be a motivater. But everything we've done has always been kind of, if she was good at something, I really didn't try to be good at that thing. And so in school, it was like she was really good at math and science, and I was perfectly willing to be horrible at that, and be good at other subjects. I think we always tried to be conscious of that, not like excel at the same thing, to do our own thing so we wouldn't be in competition with each other. (27Ji.2.1)

Jill continued to explain that her teachers and other adults often made comparisons as well. She explains further that some people seemed to expect one of them to be "better" than the other in specific subjects, hobbies, or athletic events.

> You were always compared. But I think we tried *not* to be. We were so much viewed as one entity, that if she was good at something, I should be good at it. I think it motivated us to try and be *different*, so we would have our own identities, and we did that in a lot of different areas, including academics. And I always had in my mind, feeling, 'Oh, she's smarter than me in math, in science, and all that kind of stuff.' But I don't know how much of that was really true and how much of that was just kind of self-imposed. (27Ji.2.1)

In the course of the interviews Ann revealed that she actually looked up to Jill for her willingness to take risks, being the one person in their family that lived her life according to her own goals. Ann expressed that she admired that in her sister.

Jeff and John each expressed the idea that since they knew each other's academic potential, they held each other accountable for living up to their potential. It was viewed as a positive influence on their academic work. Dan and Mike echoed the same sentiment regarding their academic abilities. They expressed the idea that when one of them did well, it helped motivate the other to do well in other academic tasks.

Jay and Carl mentioned that when they were in their senior year in high school they felt an expectation from their peers, teachers, and even school counselors to compete for their class rank. It was for a time an issue of whether they would be influenced by the college choice of their twin sibling. Eventually both chose the same university because they both thought it was the best place for them and their academic pursuits, not because their brother had chosen that university. At times they felt they had to justify their decision to others. They did pursue different programs and chose to spend time apart for during their undergraduate college programs and activities (Jay majored in biology and Carl majored in chemistry).

Applying Individual Learning Style Strategies

The success of each twin as a learner was positively correlated to their knowledge and application of specific study strategies that were consistent with their learning style. In other words, each individual revealed concrete examples of study strategies that helped them learn new or difficult information. These strategies were consistent with their learning styles. However, twin siblings seldom shared common learning style strengths.

These four pairs of twins were academically successful and were able to give specifics about how they studied and the conditions in which they could be most productive as learners. They were able to list specifics of their personal learning styles that were often different from their twin sibling. This was perhaps one of the most productive areas of this study in that it supports research on learning styles that emphasizes: knowing and implementing one's learning style leads to improved academic achievement, learning efficiency, and attitude.

One of the more unique study strategies was Dan's use of a small memo notebook on his rounds and duties as a medical student. However, instead of using it to actually record words or notes, he would use it as a tactual device to make squiggles while he was listening or being exposed to new or difficult information. When studying at home, he often did the same. He would have a tablet of paper near his desk on which he would make writing movements and lines as he read or reviewed difficult information. He specifically stated that the mere act of being tactually involved while he read or heard information helped him process that information. When Dan was asked if he tried just moving his finger over a tablet surface instead of actually writing nonsensical lines with a pen or pencil, he responded that he had tried that but it was not as effective. Mike did not use any such tactual technique.

Jay recounted times he would make maximum use of his study time under pressure by employing a sleep-study cycle. Jay explains:

> I call it my sleep-study cycle. My favorite way to study is, what I'd like to do is, I'll study that material, especially if you're reading a book, and science books and things can get pretty dry. So I'll read it for a while, and there's only so long that I can concentrate on the material. The concentrating I do is really intense and then it almost wears you out mentally after a while, like after studying for quite a while. I kind of like, ugh, 'what did I just read?' When I get to that point.... I shut the book and I'll actually just take a short nap, maybe a half-hour. So I just go to sleep, wake up, and then start studying again, as long as I have, you know, food or whatever. I can do that for hours on end. Just sleep, study, sleep, study, and it's weird cause I won't get the traditional seven hours of sleep. Whatever I sleep, if I'll sleep-study, I can do that over a twenty-four or forty-eight hour cycle. (9J.1.3)

Jay went on to explain that he has monitored his sleep-study cycles and he's reported that such cycles are an efficient use of his study time. He reported being able to remember the information following such cycles and having produced some very good papers using this strategy. He also reported times when he would, "just sit there and relax and rest my mind, almost like a meditation, just for about ten to fifteen minutes, and then I'll get myself up and study again." (10.J.1.3) Carl did not report using or even being aware of his brother's sleep-study cycle.

Carl and Jay also reported having different preferences when it came to formal or informal environments. Carl preferred a more formal or traditionally quiet desk and table arrangement in which to study. He usually resorted to a computer space at the university library to study. Jay preferred a more informal study area, which usually was in his dorm room in a comfortable chair. Jay reported trying to study at the library under more formal conditions, but he would usually resort to going back to his dorm bedroom and feeling more comfortable and productive there.

In the case of Ann and Jill, there was a marked difference in their perceptual modality preferences that contributed to their miscommunication at times. Ann's perceptual learning style strengths were visual and tactual, while Jill's preference was for the auditory mode. Each explained that these different preferences actually lead to communication problems between them. Ann would rely and recall auditory information more readily than other forms, and Jill often preferred or required visual or tactual means of communication. Jill often referred to instances when she would recall what others had said to her verbatim, and this would often amaze or confound them because they did not have such a comprehensive recall of auditory information. Ann, on the other hand, would often openly use auditory mode to share ideas with Jill, not expecting to have such auditory ideas taken as her "final" decisions. Ann's strong preference would be for final ideas/plans to be written down or involve tactual or visual representations. This was one case where discordant perceptual modalities were interfering with twin sibling communication.

John and Jeff both had a perceptual preference for auditory but Jeff had an additional preference for tactual experiences. Carl and Jay shared one perceptual strength, kinesthetic modality; however, Carl also had an auditory strength as well. Contrary to what many may have expected these four pairs shared few of their perceptual strengths or other learning style elements of the Dunn learning style model.

The Twin Advantage in Learning Situations

The participants reported instances in which being a twin actually served advantageous in learning situations. For example, it often led to early name recognition and greater attention because many teachers and their peers expressed a personal interest in twin experiences.

Jeff recalled how he liked having a twin brother because it was motivational for him, especially in learning situations. Jeff and John would often choose each other as lab partners in some of their college nursing courses, although they both expressed the case that they do not study together or review for exams together, and actually prefer to work alone when learning / studying.

Jay and Carl recalled times when they would be singled out by instructors in their formal school experiences. Such occasions would often allow them to receive attention, which lead to early name recognition. It was also an opportunity for instructors to later see them as individuals. One professor, having taught them each a college science course in chemistry, commented that Jay and Carl approached chemistry from their own unique perspectives. Carl remarked that he liked being recognized for his own abilities and liked the informal conversations he would have with some of his professors during their office hours.

Another advantage of being a twin, according to John and Jeff, Jay and Carl, and Mike and Dan is that of having someone with whom you can communicate efficiently. Their peers and friends were often amazed at the conversations between twin siblings. The ease and brevity of conversations between twins was often reported. The communication patterns were unique largely due to these twins having such a common and shared history of experiences. It is similar to married spouses who may communicate entire thoughts or ideas with a simple expression or trite phrase unrecognizable to observers.

Jill and Ann also supported the idea that often times group work / group learning situations were ineffective for them largely because such groups were often disorganized and inefficient ways to meet specific objectives. This sentiment was echoed by all four of these pairs of twins. Their initial preference for study or learning arrangements were for each sibling to work alone. A second grouping option was to work with others who were as motivated as themselves. However, contrary to what one might expect, none of these individuals preferred learning in groups, or even learning with their twin sibling. In all of the twins interviewed their expressed social preference for learning was alone/by themselves.

All of these individuals also expressed frustration at not being given options to work alone in school situations. Group work, especially in large groups of five or more, was one of the worst ways to communicate and process information for Dan and Mike. They echoed the sentiment of the other three pairs when they commented that "if you want us to do poorly at a learning task, put us in a large group situation."

Individual Recognition and Individual Identity

The participants in this study, especially in learning environments, commonly expressed the need for individual recognition and individual identity. The need and the struggle to be viewed as individuals, without always being compared to their twin sibling, was frequently expressed. This theme revealed the unique challenges of being thought of as an individual when at times even long-time close friends and teachers would make incorrect assumptions and unfair comparisons.

Each pair interviewed expressed struggling with their establishing an individual identity apart from their sibling twin. John and Jeff went so far to say that they often spend more time on the weekends at their girlfriend's home and with her family because there they were seldom compared with their brother. They would frequently study at their girlfriends' houses rather than at their own home.

Dan and Mike expressed concern over drawing too much attention to themselves as twins in medical school and around the hospital. They would often commute to school or the hospital together; however, one would enter the building before the other or by using a separate entrance to avoid being seen together and thus attracting stares / being considered as 'a unit.' Dan and Mike commented that even some of their long-time friends would not always distinguish between their individual preferences and mannerisms.

John and Jeff expressed the same struggle with their parents and with the people they worked with at the hospital. When one had done an excellent job or was commended, the compliment was often awarded to "the twins." Their parents too, would at times consider them as sharing the blame or accommodation for specific accomplishments or mistakes made by only one of them.

As mentioned earlier, Jill and Ann had expressed the need and attempt to develop individual identities by choosing carefully the subjects in which they would excel. They too, regretted the times they would be expected to compete with each other in academic and non-academic situations. They also regretted the times they were expected to be alike or show similar preferences for recreational activities. For example, as children, if Ann wanted to see a particular movie, it was sometimes assumed that Jill wanted to see it as well.

Carl and Jay expressed their sentiments regarding their choices to attend different graduate schools and finally being apart from each other after seventeen years of attending the same academic institutions. Carl expressed it this way: “in graduate school it will be ‘Carl,’ not ‘Carl, the twin.’ No one will even know I’m a twin unless I choose to tell them.”

All of the twins in this study expressed a preference for being called by their name, even if they were mistaken for their twin sibling, and called by their name. They would much prefer that instead of being referred to as “the twins,” or as one of the “Smith twins,” or by some other unifying phrase. This too, was observed as a way of avoiding acknowledging their individuality by their peers and teachers.

The Importance of These Themes

These vignettes and the emergent themes illuminate the need for parents, teachers, and friends of twins to become aware of their own behaviors and the consequences of those behaviors on twins and their learning. What follows are some key points and applications that educators and parents could be made aware.

- Parents and adults should *encourage and engage twins in informal and non-formal learning activities*, especially in the early, elementary, middle, and upper grades.
- Acknowledge each twin as having *individual learning preferences and get to know twins as individuals.*
- *Be wary of competition between twins*, especially when such competition involves academic performance.

- Encourage and *help each twin to discover, develop, and accommodate their individual learning style preferences.*

Such detailed and rich stories told by twins about their learning experiences indicated the need and value of continued qualitative research on twins and their learning styles. A recently published book: *Twin and Triplet Psychology: A Professional Guide to Working with Multiples*, (Sandbank, 1999) offers guidelines and research to be considered by parents and professional in working with twins and multiples. The themes that emerged deserve further investigation to be more fully understood by the learning community. Likewise, the learning community stands to benefit by considering the ways it consciously or unconsciously treats twins in formal and non-formal learning situations.

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A COLLABORATIVE EFFORT BETWEEN EDUCATION AND SCIENCE FACULTY TO IMPROVE THE EDUCATION OF PROSPECTIVE PUBLIC SCHOOL TEACHERS

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The science requirement for the elementary education major at Indiana University-Purdue University Indianapolis (IUPUI) is 15 credits of science which must include a course in biology, physical science, and earth science. None of the courses that elementary education majors are required to take from the School of Science has a laboratory component and, typically, these courses are taught in large-enrollment lecture courses taken by students from all of the schools in the university.

This approach to introducing future elementary teachers to scientific disciplines is used at many universities because it is usually impractical to schedule special sections for education majors. Therefore, they must learn science by taking the courses designed to provide a measure of scientific literacy to the general public. For a variety of reasons, these courses do not, in fact, improve students' scientific literacy. For example, de Caprariis (1997) contended that the structural differences between courses intended for science majors and the survey courses for non-majors prevented most students from learning how science is actually done. And the results of a major research project involving several universities that studied secondary science and mathematics teacher preparation programs in the United States agreed, noting that science majors reported positive experiences in their classes that provided close contact with their instructors

(Robinson & Yager, 1998). However, they felt little or no relationship with faculty who taught large survey courses.

In an attempt to address the needs of elementary education majors in particular, and non-science majors in general, a pilot project that involved faculty in the School of Science and School of Education at IUPUI was organized and implemented. The project was designed to test the integration of small group activities in an introductory Environmental Geology course that traditionally has been a "lecture course." It was believed that the collaboration between students working in small groups would provide two benefits. First, students would be actively involved with responding to the exercises and active learning experiences are considerably more likely to illustrate the logic behind the subject studied than passive reception of information in a lecture. Second, because peers are "closer" to each others' zones of proximal development (Vygotsky, 1962) than any instructor can be, peer instruction can be more effective than lectures.

During the Spring, 1999 semester, students, in the course described in this paper, were involved in close interactions with their peers. This paper discusses how the course was organized and contains details about some of the small group activities that were used in the class. In addition, evaluation data are discussed that were collected during the semester. The data are related to students' understanding of major science concepts of the class and their perceptions of the value of the small group activities. The major conclusions reached during the field-testing of this course, were that small group activities can be implemented in large enrollment sections and that assessment of the success of the activities can be obtained without a great deal of difficulty.

Structure of the Course

The traditional lecture format for the Environmental Geology course was altered by using one of the two class meetings each week to introduce collaborative exercises. This was done for 10 weeks of the 15 week semester. The course met on Monday and Wednesday mornings; traditional lectures were delivered on Mondays and the exercises were used on Wednesdays. When feasible, the lectures were used to introduce the material covered in the exercises, but depending on the schedule, sometimes the topics were introduced by the exercises. Two examples that illustrate the kinds of things done involve earthquakes and coastlines.

At the end of a lecture on earthquakes, the students were asked to examine a Web site prior to the next class that deals with the New Madrid earthquakes of 1811-1812, and, based on eye-witness accounts, students estimated the Mercalli Intensity (a measure of the damage done locally) at Evansville, IN. In the next class, they compared their estimates with the students in their group. Then they used a map of predicted intensities that showed the worst case scenario for future events in the area to estimate the kinds of damage that would likely occur in Central and Southern Indiana from such an event. The exercise is displayed in Table 1.

The material on coastlines was scheduled to begin on a Wednesday, so the exercise was the students' introduction to the subject. Earlier in the semester, they heard a lecture about closed systems, and later in the semester, they applied the material to watersheds. For the section on coastlines, they were asked to learn some terminology by reading the section in the textbook on barrier islands prior to class. Then, in class, they constructed a model of a beach and discussed the validity of the assumption that beaches are closed systems.

Table 1

Exercise on Earthquakes

1. You were asked to estimate the probable damage in Evansville, IN from a magnitude 6.5 earthquake in the New Madrid, MO region before coming to class.
2. Compare your estimates with those of the students in your group. If you do not agree with them, justify your decisions. Try to convince them that you are correct.
3. There is a 50% chance that a magnitude 6 earthquake will occur in New Madrid in the next few years, and a 90% chance that it will occur in the next 40 years. With your group, estimate the kinds of damage that would occur in Indianapolis from such an earthquake
4. Now think about your home. Make a list of the things that could happen in your kitchen from a magnitude 6 event in New Madrid.
5. Now consider the effects of a magnitude 8 event in New Madrid. Make another list of what would probably happen in your kitchen.
6. Are there things you could do now to reduce the amount of damage in your home from an earthquake in New Madrid, or anywhere else in the Midwest? What might they be?

All of the work for these two exercises, and the other eight they did during the semester, was done in groups of four to eight students. A few students refused to work in groups and were allowed to do the work on their own. The rest quickly got used to working with their neighbors. No effort was made to determine who was actually doing the work; we were satisfied as long as the entire group seemed to understand the concepts, and as long as no one complained about "carrying" those who did nothing.

Assessment

Oral interviews were conducted at the beginning and the end of the semester with education majors in the class. Initially, 12 students were identified to receive the interviews. However, due to attrition, only 8 students received both the pre and post interviews. The interview questions pertained to major class topics, and students were asked to discuss them in as much detail as possible. The questions used are shown in Table 2. The student-responses are shown in Table 3, along with the scoring rubric that was used to assess student understanding.

In addition to the interviews, students were asked to use the end-of-semester course evaluation forms to make written comments about the value of the group exercises. A few of the comments were negative, but the overwhelming majority of them were positive. Most students liked the change from the standard lecture format and felt that they were able to learn more from the exercises than from listening to lectures.

The last measure of assessment addressed the efficacy of the exercises more directly. The final examination in the course has always been a 100-question multiple-choice test. This format was also used in the spring 1999 semester. No new topics were introduced, so the majority of the questions were similar or identical to ones that had been used in the last few semesters. A few of the questions were modified a bit so that they clearly pertained to the work done in the exercises. This was done to reassure students that the work they did in the exercises was considered important enough for them to be tested on it. Because the bulk of the questions were similar to ones that had

Table 2

G107 Interview Questions

1. Please complete the following statement: The chances of having an earthquake in Indianapolis in the next 20 years is A. unlikely B. somewhat possible C. very likely. Please explain your answer to this question.
2. How can only 3 to 6 inches of rain within a 24-hour period cause a river to rise several feet?
3. Do you think the Earth is experiencing global warming? Please explain your answer.
4. A common belief is that: "The solution to pollution is dilution." Do you agree with this statement? Why, or why not?

been used in previous semesters, performance on this examination can be used to determine the effect of the exercises. If the performance in the spring 1999 semester differed from that in previous semesters, we could infer that the exercises were at least partly responsible.

Interpretation of the data

It is not possible to conclude from the interviews (Tables 2 and 3) that the collaborative activities were successful or unsuccessful because the sample size was small and the interviews were not used in prior semesters when the format was strictly lecture. In addition, for a variety of reasons, we should not expect a small number of students to "score well" on all four categories used in the interviews. To mention just one reason, some students will not be in class when a topic is discussed.

Table 3

Student-Responses to the Questions

Student	Earthquakes	Flooding	Global Warming	Pollution
1	1/3	0/3	1/2	1/1
2	1/3	0/1	1/2	1/1
3	2/2	2/3	0/2	1/3
4	1/1	0/0	0/2	2/3
5	1/1	0/1	0/1	2/3
6	3/3	0/0	1/2	2/3
7	2/3	2/3	1/2	0/3
8	0/1	2/3	0/1	0/3

The first number for each topic is the value obtained at the beginning of the semester and the second number is that obtained at the end of the semester.

Scoring Rubric:

0 - Student says he/she does not know how to answer the question.

1 - Student tries to answer the question but does not have any previous knowledge to assist in answering it. Student does not use any information from class to answer the question.

2 - Student may have some previous knowledge of the topic and may use some terminology related to the topic. But, student does not use any information from class to answer the question.

3 - Student answers the question correctly. The student incorporates information from class into the answer.

Note: the statements in rubrics 1, 2 and 3 that refer to using class information to answer the question pertain to questions asked at the end of the semester.

Ordinarily, the small sample size would not constrain interpretations greatly. But the group interviewed was not chosen randomly; only education majors were chosen because we were mainly interested in knowing how they perceive the subjects covered in the course. In retrospect, we should have interviewed some students majoring in other areas to see if any differences between disciplines could be observed. Yet, scheduling the interviews twice in the semester proved to be a formidable task. Interviewing a larger number would have been much more difficult. However, the interviews do provide information about some students' understanding of the topics taught in the course (table 3). The mean scores at the beginning of the course differ significantly from those obtained at the end for three of the four questions ($p<0.05$). A qualitative comparison of the differences also provide useful information. It reveals that:

- No one scored lower at the end than at the beginning, though the responses in 8 of the 32 "boxes" in the table were the same before and after.
- Based on the last statement, three-fourths of the responses were higher at the end than at the beginning.
- Only 1 student scored 3 at the beginning of the course, but all 8 scored 3 at least once and as many as three times at the end of the semester.
- There seems to be no pattern with respect to time. Four of the eight students scored 3 at the end for Earthquakes and Flooding, topics which were covered early in the semester. Six of the 8 students scored 3 at the end for the question on pollution, a topic which was covered midway through the semester. But no one scored 3 for Global Warming, which was covered late in the semester. Clearly, the Global Warming exercise needs to be revised.

These results are gratifying because they show that by the end of the semester, a sample of the students were using class information (i.e. scoring 3) in some, if not all, of their responses, even if the material was covered in the first half of the semester.

Comparison of the Spring 1999 group's performance on the final examination with that of previous groups is shown in Table 4. In that table, the beginning and final enrollments are given, as is the dropout rate (% attrition). The mean and variance of the grade distributions are also given. The mean is a stable statistic, and should not be expected to change much over time. On the other hand, the variance is sensitive to outliers, such as very low grades, so we use the variance as a diagnostic criterion in comparing these performances over time.

Table 4

Data on Student Performance for five semesters

	Spring '97	Fall '97	Spring '98	Fall '98	Spring '99
Beginning enrol	60	53	69	60	65
Final enrollmen	52	46	56	50	56
% attrition	13	13	19	17	14
Mean grade	66	68	67	68	68
Variance of the grades	155.2	135.3	84.6	163.8	99.2

For the five semesters shown in Table 4, enrollments were fairly stable, as was the mean grade on the final examination. But the variances show differences. The two lowest values, for Spring 1998 and Spring 1999 are considerably lower than the others. If the group exercises contributed to students' learning of the basic concepts of the course, one might expect a smaller variance for the Spring 1999 semester. However, the low value for the Spring 1998 semester must be considered if we attribute a positive influence to the group work. Therefore, it is important to note that the Spring 1998 section had the highest attrition rate, which, by itself could explain the low variance of the grade distribution. In addition, examination of the grades students received in the Spring 1999 section (when the group exercises were introduced) shows that the lowest grade on the final examination was 33%, considerably lower than the next lowest grade. That student also failed the two mid-term examinations and received failing grades on the four writing exercises assigned during the semester. Class records show that over the last six semesters, most students in that condition withdraw from the course, so ordinarily, this student would have withdrawn long before the final examination. For some reason, the student chose to remain in the course. If we neglect this student's grade on the final examination, the attrition rate for that semester changes marginally, but the variance of the grade distribution decreases from 99.2 to 70.8. This value is lower than all of the other variances, the Spring 1998, indicating that one student's performance can affect the variance significantly. As a check of this conclusion, we examined the grade distribution for the Fall 1998 semester, which has a high variance and a high attrition. The grades show that a single student was responsible for the high variance in that semester also. Neglecting that student's grade on the final examination would also lower the variance for that semester. So the conclusion that the persistence of one student distorted the record of the Spring 1999 semester seems warranted.

Conclusions

The low value of the (adjusted) variance for Spring 1999 suggests that the introduction of collaborative exercises during that semester had a notable effect on student learning of the basic concepts of the course because it indicates that student learning was more uniform across the class that semester than in previous semesters. This conclusion would be strengthened by more data, so group exercises will continue to be given in subsequent semesters, and a multiple-choice final examination will continue to be used as a control instrument.

One problem with the group exercises is that using them on a particular day of the week sometimes interferes with the presentation of lecture material. In an attempt to introduce the material in the exercises in a seamless manner, in the future they will be used one or two problems at a time, in the lectures themselves or when they are appropriate.

We are not trying to justify collaborative exercises in undergraduate education. The active nature of learning when students work together needs no justification; it is clearly better than the passive reception of material in the standard lecture approach to teaching. But we feel that we have demonstrated that collaborative exercises are not restricted to small classes; they can be used in moderately large classes, even in standard amphitheater-type lecture rooms. During the Fall, 1999 semester, the instructor of the course continued the experiment without assistance from the education faculty, showing that one instructor can easily monitor students' group work in a class of 60 students. Implementing this approach in larger classes would require the presence of teaching assistants.

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HOW MIDDLE CHILDHOOD IN-SERVICE TEACHERS VIEW THE “SCIENTIFIC METHOD“

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Most late elementary and middle school texts have an introductory chapter in which the scientific method is described. A typical earth science text states “Scientist use a series of planned steps, called a scientific method, to solve problems.” The reader is then instructed to examine a table in which the following steps are shown: (1) Define the problem, (2) Make an hypothesis, (3) Test the hypothesis, (4) Analyze the results, and (5) Draw conclusions (Feather & Snyder, 1997). Texts for younger children often give the following as the step in the scientific model: (1) Observe a natural event, (2) Question the event, (3) Make an hypothesis, (4) State a prediction, (5) Test the hypothesis, and (6) Explain the results. Both of these imply that the way scientist “do” research is by following a defined set of steps. Few texts give any indication that these steps may be revisited and modifications made.

Many practicing teachers were taught this very same series of steps for doing science when they were in elementary, middle, and high school. In fact, most of them engaged in activities that were called science experiments in which this was the process use. As teachers of science, they find that the texts are still stating that these steps are the way that real scientists work and should, therefore, be the way that children experience science. This may be the reason that many middle childhood teachers plan experiences for their students that try to mimic this method. They may not have a true understanding of how research is conducted.

Almost 50 years ago, Anderson (1950) concluded that teachers were more concerned with imparting scientific fact than helping students understand the processes of science – an indication that something was wrong regarding teachers’ notions of the nature of science. In

1978 Cawthron and Rowell concluded that science teachers take a naive-realistic position of science, maintaining that scientists have particular characteristics and employ scientific methods to account for the achievements of science. The Benchmarks state "Scientific inquiry is more complex than popular conception would have it.... It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as "the scientific method" (AAAS, 1993, pg 9). A consensus of eight international Science Standards documents found "There is no one way to do science (therefore, there is no universal step-by-step scientific method)" (McComas, at al. 1998). Therefore, there would appear to be a need to continue this line of research by not only assessing what teachers think about the scientific method but also looking at how it can change with an intervention.

Purpose

The purpose of this investigation was twofold: (1) to explore middle childhood in-service teachers' concept of what the "scientific method" is and (2) to explore ways in which the concept of "scientific method" changes as middle childhood teachers engage in reflective activities concerning the scientific method. Educators of teachers of science are constantly trying to improve methods and content courses in order to prepare better teachers. This research is intended to add to the growing body of knowledge in this area.

Method

Participants and context

This investigation was conducted in the College of Education at a research university located in a major metropolitan area in the southeast. The participants were 32 students, 7 males and 25 females, enrolled in two sections of masters level "Concepts and Issues in Science" course for middle childhood majors. All of the students had been teaching for three or more years. Some of the students had undergraduate degrees in education, while others had gotten their initial certification by an alternative route. Students were at different stages in their graduate work, with some having already begun working on the masters thesis and others being in their first term. Of the 32 students, the researcher had taught 12 students in the undergraduate methods course, one in high school biology, and eight in on-going in-service workshops supported by their districts.

Procedures

Activities with students

The students were divided into work groups on the first day of class and each remained in the same group all term. At the beginning of one of the class periods, the students were shown the words "Scientific Method" on the overhead and asked to individually write a description of the images evoked by these words. After the students had developed a personal description, each group was asked to convene and decide on a group description. The individual and group descriptions were collected.

Student groups were then given an envelope containing slips of paper on which phrases were written. The eight phrases were: Recognize the problem/Ask question, Hypothesize an answer, Predict a result based on your hypothesis, Look for existing research in the area, Rephrase the question, Devise and perform an experiment to check the hypothesis, Report the results, Develop a theory that links the hypothesis to previously existing knowledge. The envelopes contained several duplicates of each phrase. The groups were instructed to use the word strips, tape, magic markers and butcher paper to create a graphic organizer that would depict how someone would actually go about conducting research. They were told that they could delete any that they felt were not needed and add any that they thought were missing.

Upon completion, the graphic organizers were displayed around the room and each group explained their representation to the class. Near the end of the class period, the students were asked to compare the group description of the scientific method with the process of doing research as depicted in the graphic organizer.

At the end of the class period, the graphic organizers were collected and the students were assigned to interview a scientist about his/her work. The interview protocol was semi-structured with one of the questions asking the scientist about the “scientific method” as depicted by textbooks. After the interview, the students were to write a short paper comparing the scientists’ method of working with their description of the scientific method and with their graphic organizer.

At the next class session, which was one week later, the groups were given time to talk about their interviews and how it affected their ideas of the “scientific method”. After the open discussion/debate, the groups were given time to edit their graphic organizers if needed.

The assignment for the next meeting was to write a reflection paper about the entire experience. Students were to think about their initial response to the overhead, the group description, the graphic organizer, the interview with the scientist, and any edits to the graphic organizer. They were to include reflection on how this experience would effect them as a science teacher. The researcher at the next class meeting collected the reflection papers.

At the end of the term all students were asked to have a 30-minute conference with the professor. This conference was not specific to the scientific method activity. The conferences were audio taped.

Data Collection

Data were collected using several methods in order to get the best "picture" of what the students thought at the beginning of the term, their exploration of the topic, and any change that occurred. The researcher took very brief notes during the class, kept a journal, collected audio tapes of all small group work, video taped all class sessions, made copies of student work, and conducted an end-of-the-term conference with each student.

During the first session, the researcher took notes of the conversations as the groups worked on the project and on the final discussion. Audio tape recorders were place with each group to capture the discussion and the session was video taped using a camera permanently suspended from the ceiling. The same procedure was used during the class in which the students discussed the interviews with a scientist. Student papers were collected and copied. Original work was returned to the students at appropriate times.

Analysis

Data analysis did not occur until after the end of the term. In order to explore what middle childhood in-service teachers thought about the scientific method at the beginning of the term, the researcher reviewed her notes and journal entries from the first class as well as the audio and video tapes. She also reviewed copies of the original statements about scientific method.

In order to explore ways in which the concept of scientific method changed, she watched the video tapes and read the transcripts of the first class activity as they developed the graphic organizer. Similarities and differences were noted among the groups. She continued the process of reviewing the audio and video tapes of the class sessions and reviewing copies of the student work. Themes were noted.

Results

The individual descriptions, as well as later reflections, revealed that the students began by thinking about the scientific methods as being very linear and well defined. They all wrote a very standard statement or actually listed the steps as found in many textbooks or wall charts. Thirty students had five steps to the process, one had six and one had four. In all seven groups, the consensus was a list of steps similar to those found in most middle school texts. All seven groups had five steps. As the audio tapes revealed, coming to consensus was a very fast process with very little debate/discussion as the students quickly agreed on the steps.

The groups began the graphic organizer activity by pulling out the word slips and arranging them in the "proper" order. The first conflict in views was noted when the groups realized that they had too many strips. Karen and Alisha express a common theme seen in all the groups.

> Karen: Look, we have strips that belong to another group. (voice loud) Hey, is any group missing some strips? We seem to have too many.
>
> Alisha. This has to be a mistake, these aren't the same as the poster I have on my wall. (The wall poster is in her classroom and came from ABC supplies.)

When the groups discovered that they had two or more of each word slip, they informed the researcher/teacher that a mistake had been made and that too many words were in their envelope. They were told that there was not a mistake: they could use the extra word slips or they could throw them away. At that point, the group discussion became very animated with lively debates about what to do with the extra word slips, what is research, and how is research really conducted. In each group, someone suggested that the extra word slips be discarded while someone else suggested that maybe they should try to use them. The dialogue between Marty and Beth is an example of the conversations occurring in the groups.

> Marty: She just gave us these to see if we know the steps.
>
> Beth: No, I think it is important that we have more than one.
>
> Marty: Beth, I don't think we need them, remember the wall chart (found in her classroom).
>
> Beth: What about the rest of you, should we throw these out?

Students who had some experience with research (either their masters thesis or work in a lab) began to tell about occasions when they had deviated from the linear model depicted in most texts.

> Kathy: I remember wanting to know the answer to a particular question and then reading to see what others already knew. That helped me focus my question and then I thought about how to set up the research. Thinking about how to go about it made me rethink my question and that made me read some more. I guess what I am saying is that I still had the basic question but had gone around the world to even get to the start of the real research.
>
> Kent: Now that I have these extra words, I don't think that my description was a good one. I mean, I don't, you know, think it is just five steps.

Students then began to add duplicate word slips to their graphic organizer. The results were graphic organizers, which did not look like the charts in most texts. Students explained to one another that they were happier with the organizer than with the earlier description. Transcriptions of tapes and analysis of the graphic organizers revealed that the students' graphic organizers were more complex than the original group description. Arrows were used as well asslip placement to show the more complex ideas (Figure 1).

> Betty: Think about the plant experiment we did. I mean, we went back and forth. I want to draw arrows going back and forth.
>
> Camille: I think research is more than just the steps I first wrote.
>
> Karen: This is getting confusing, you know, I thought the scientific method was about research but when I really think of research, well, I guess I don't think in steps. Well, or of steps, I mean, I do but I don't.

At this point the one group began to see research as done differently by middle grades students, high school students and real world researchers. Figure 1 shows this graphic organizer.

> Roger: You know, I remember my high school labs and we never really did a true experiment. We just, uh, followed the steps. Now, my students [middle grades], really have to think up real experiments. I think they do it differently.
>
> Fofona: Yes, in real research you move among these steps. I think it is more like the middle grades than what you described as high school science.

The students in all of the groups decided that arrows should be used to show that there could be movement back and forth. Some groups decided to arrange the word strips in a circle, but most used a more typical top to bottom orientation. Only one group decided that research is done differently at different levels.

During the next class session, the students reported on their visit and interview with a scientist. They also shared their thoughts about the scientist and the scientific method as they first described it and as they depicted it in the graphic organizers. The scientists ranged from university-based to industry-based. All were working on original research projects. No student reported that the scientist used a linear method of research. Many of them reported that the scientist often worked “in circles”. The closest to linear was a CDC scientist. After the students had interviewed a scientist, no group edited their graphic organizer to be more linear. The papers revealed an astonishing amount of change in the students’ ideas of the “scientific method”.

> Sonya: Dr. Jones is trying to figure out a cure for some exotic African fever. She works at CDC and the basic research question is “What is the cure for what ever this disease is?” and she just keeps plugging along, you know, looking at all the possibilities. Her question does not really change, and she does hypothesize something and tries it and then draws a conclusion. So far the conclusion has always been No Cure. But, well, the question does not change and she still tries something else and she reads all the time. Somehow, it did not seem like the step-by-step process our kids do and call science.
>
> Lauree: My scientists is doing the weirdest stuff. I mean, I can not even tell you what he does, something with nuclear reactors. Did you know that (name of institution) has a hugh reactor? Like, it could blow us all up. But, anyway, he is trying to discover how to make better energy, not really better, but cheaper. He had to even think about what the scientific method is. I mean, he does not even think like that.
>
> Ann: Dr. Johnson just said, “you know, the science I love is far more fluid than the process you just described”.

The last assignment was to write a reflective paper. Having thought about the scientific method, interviewed a scientist, debated with each other, and reflected on the whole process, students stated that they would never again think of research as following only one proscribed method.

> Beth: I can not believe that the textbooks make science seem so cut and dried. The research I have seen this term and the interview with a scientist makes me see that my rote description is so off base. How can I expect my students to think like scientists if I have them memorizing a set of steps that only partly tell the story?
>
> Sonya: This is the first time that I have even questioned the description I memorized in the fifth grade. I always thought research was done by always following the steps. Even hearing about "surprises" like penicillin, I still thought of scientific knowledge all coming from a set procedure. Can you believe that I believed it then, believed it now, and have been teaching my students the same old thing? I mean, like, they will think science is just a cookbook series of steps. All the life goes out, I mean….. Dr. Zolinski was so full of his work. I mean, he never talked about it as if he just did steps.

Several weeks later, the students had an end-of-the-term conference. The researcher did not bring up the topic of scientific method. However, twenty-one of the thirty-two students initiated a discussion about the activity. In each case, the student expressed a positive attitude toward the activity and change in his or her feelings about the scientific method.

> Kent: Several activities we did helped me see science as a much more human work. Talking to my scientists was so great. He really helped me see that what he is doing is just like a detective. Gee, he was really into his work.
>
> Marty: What I want is to work beside a scientist. I want to watch the process, because now I know that it would not be, you know, just following a set of predetermined steps.

> Camilla: I loved interviewing a scientist and seeing how her work compares with the scientific method. I mean, I have that chart on my wall. I have, well, I have students memorize it. Ugh. Like it is THE way. Not like it is a general outline of the way. I mean, I know Dr. Roberts kinds of followed it but, you know, not just step-by-step.

Discussion

Several patterns emerged from this study. The first was the reaction by all the in-service teachers as they defined the scientific method. They all felt very comfortable with describing the scientific process as definite sequential steps. When coming to consensus, they quickly agreed upon a description. The second pattern was seen in the rich discussion that occurred as the groups developed a graphic organizer. All of the groups began by trying to use the word strips to show the same steps that they had described earlier and deciding that a mistake had been made in the number of strips that they had in their envelope. They then began to debate the arrangement of the strips and quickly drew on past experiences as examples of when they did not follow the steps. The group discussions as word strips were arranged and rearranged indicated that the groups were not really comfortable with a five step method. Finally, they began to use the colored pencils to show how a researcher might move back and forth between steps. The graphic organizers that resulted were all less linear than the earlier descriptions.

A third pattern was seen as a result of the visit and interview with the scientists. Most of the students were amazed at how "human" the scientist was and how much the scientist enjoyed his or her work. After listening to the reports, no group edited the graphic organizer.

In addition to the patterns seen with the two classes, several interesting ideas for educators of teachers of science emerged from this study. The first one was the in-service teachers' initial reaction to the words Scientific Method. Having students graduate from colleges of education certified to teach science who believe that scientific inquiry can be captured in five or six sequential steps is not encouraging. These students were very confident in their ability to describe the scientific method by just listing five steps. They, like the participants in the Anderson study (1950), appeared to be more concerned with being able to give a concise definition of "scientific method" than in really helping students understand the processes of science. This may indicate that science education courses are not helping the students to gain a greater understanding of science themselves.

The second interesting idea was how quickly the students began to question their own ideas and descriptions. Within a very few minutes of trying to create a graphic organizer, they were beginning to build on one another's experiences and to express doubt as to the accuracy of the five-step method that they had described. Their own experience seemed to show that the scientific method is more complex than they had originally professed it to be. Being able to discuss their ideas within their groups helped them clarify what they really thought the scientific method should look like. They did not discard the steps completely, but used them to create a more complex idea. Being able to show two-way arrows eliminated some of the stress for several of the groups.

Also interesting was the group who thought that high school science was even less "real life" than middle school science. Research on attitudes and interest in science has pointed out that children come to school with much more positive feelings about science than they leave school having (Morrell & Lederman, 1998; Weinburgh 2000). No other group edited their graphic organizer to show this same phenomenon but no one really questioned this group's interpretation of what science looks like as a student progresses in school. This conception of "school science" and "real science" needs to be investigated further.

Another interesting idea emerged as the students wrote about their interview with a scientist. They did not want to do this assignment but found it to be one of the most beneficial of all the assignments. They were exposed to environments and people that helped break the stereotypes of the "lone scientist." Many of them expressed the desire to have more contact with a scientist which would add to the research concerning programs that pair teachers with scientists.

Overall, the activities described in this paper did seem to help in-service teachers rethink their concept of the scientific method. The students appeared to leave the course with a much more realistic idea of how research is done.

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Table 1

Steps in the Investigation

1. Class activity: Scientific Method Activity
    - Individual description of “Scientific Method”
    - Group consensus of a description of “Scientific Method”
    - Group activity of creating a graphic organizer
    - Comparison of the description with the graphic organizer
2. Assignment
    - Individual interview with a scientist
    - Paper: scientist’s comments vs description and graphic organizer
3. Class activity
    - Sharing of interviews with entire class
    - Editing the graphic organizer
4. Assignment
    - Reflection paper
5. End of term conference

Table 2

Graphic Organizer

Recognize the problem/ Ask questions

⇓ ⇓

Look for existing research ⇓ ⇔ Rephrase the question

⇓ ⇓

Hypothesize an answer

⇓

Predict a result based on your hypothesis

⇓

⇑ ⇐Devise and perform an experiment

To check the hypothesis

INTRACAMPUS AND INTERCAMPUS COLLABORATIONS: LESSONS LEARNED

Laura Henriques, California State University, Long Beach
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Project ALERT (Augmented Learning Environment for Renewable Teaching) is a collaborative effort between the California State University (CSU) system and two California-based NASA centers. The overarching goal of the project is "to promote awareness, appreciation and understanding of the earth to millions of students and their families" (Ambos & Ng, 1998; http://projectalert.nasa.gov/mission.html). The focus of ALERT's current efforts has been on reforming earth science instruction for prospective teachers in the hope that this will positively impact their understanding and delivery of science content in the K-12 classroom. The partnering of NASA and CSU builds on the best of what each institution has to offer to this endeavor. NASA has a wealth of data, technology, and images to enhance both general and pre-service teacher education, whereas the CSU offers both content and pedagogical expertise.

Background

The concept of ALERT was born in 1994 through informal partnerships between CSU, Long Beach (CSULB), San Diego State University, several Historically Black Colleges and Universities, and Jet Propulsion Laboratory (JPL). The partnership was nurtured and encouraged through continual interactions between CSULB, San Diego, JPL, and the nationwide Universities Space Research Association-Earth Systems Science Education (USA-ESSE) program. The fruits of the initial "pilot" partnership included production of simple web-based lesson plans using NASA images as well as input to well-known NASA educational products such as "Geomorphology from Space", and the first CASDE (Consortium for the Application of Space

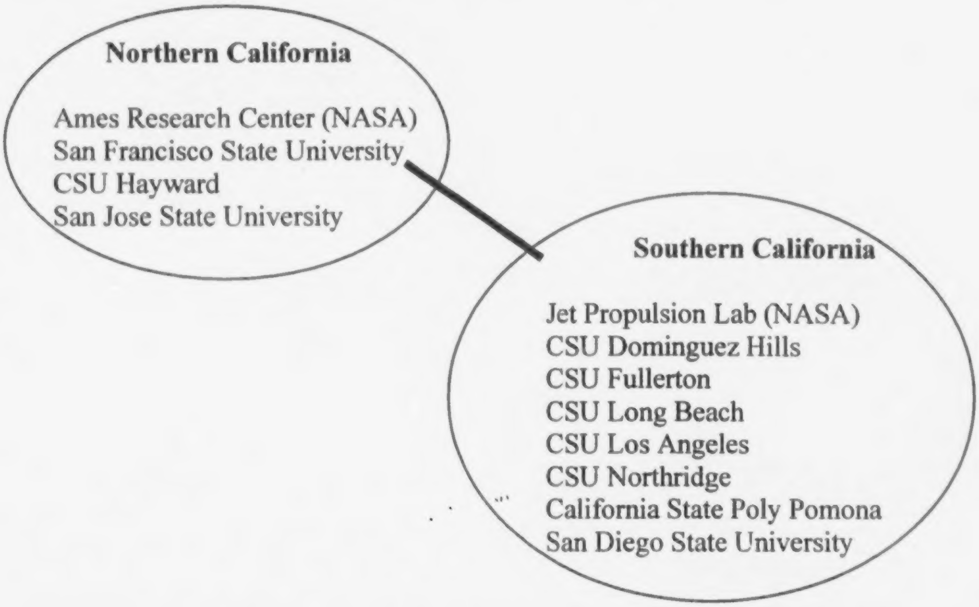
Data in Education) educational CD-ROM. These initial collaborations often included classroom-based assessment of educational products, one of the hallmarks of the ALERT model as it now stands.

With the evolution of the ALERT model as it currently exists, faculty from earth science and education are partnered on each CSU campus. In addition to their earth science-education partnerships, CSU faculty are also paired with NASA education outreach, thus bringing expertise in content and pedagogy into the design of NASA educational products and policies. Likewise, introducing NASA technology, data and images into pre-service courses means that California's teachers of tomorrow will be better equipped to use that technology and data in their own classrooms.

As one of the largest educational institutions in the world, the CSU enrolls well over 300,000 students on 23 CSU campuses spread throughout the state. Eleven of these campuses are currently involved in ALERT (see Figure 1). CSU bears a large responsibility for teacher preparation in the state, with over 50% of all teaching credentials awarded yearly by the CSU system schools.

More recent background that has influenced how ALERT is implemented and supported on campuses includes a CSU-wide mandate to develop undergraduate, integrated teacher education programs (ITEP) for elementary school teachers. These programs are integrated in the sense that they blend content education, pedagogical principles of teaching, and early field experience together into one 4- or 5-year program of study. In the plan that has been in place for over 30 years prior to the chancellor's mandate that campuses develop ITEPs, students who wish to teach elementary school major in Liberal Studies for their bachelor's degree, and then enter a fifth year teacher education program for their teaching credential. Under this design, undergraduate students are not allowed to take education courses; i.e., they must wait until their fifth year credential program.

Figure 1.
Partnerships within the ALERT Consortium


Northern California
Ames Research Center (NASA)
San Francisco State University
CSU Hayward
San Jose State University
Southern California
Jet Propulsion Lab (NASA)
CSU Dominguez Hills
CSU Fullerton
CSU Long Beach
CSU Los Angeles
CSU Northridge
California State Poly Pomona
San Diego State University

Participants on CSU Campuses: at least one scientists and one educator per campus
Scientists: Geologist, Geographers
Educators: Science Educators, Elementary Educators (generalists), Earth Science Educators

Note: The timing of the integrated, or blended. program coincided with the start of Project ALERT. This was most fortuitous as the integrated program brought together content and pedagogy experts on each campus. ALERT was already pushing these two groups to work together in the area of earth science education. Efforts from ALERT and integrated programs compliment each other.

As it relates to ALERT, ITEP has brought faculty together from across the campus to discuss the best way to integrate content and pedagogy. Education faculty and content faculty were required to figure out exactly what an integrated program looks like. It is safe to say that the programs look slightly different on each of the 23 CSU campuses. What is common across campuses, however, is the fact that faculty from diverse fields were working together. Many ALERT participants were active on their campuses in developing the new program.

Before discussing the types of collaborations and the lessons learned from each, it is important to define collaboration. As an exercise, we led the participants through an activity where they defined collaboration, listed specific project features or activities that were collaborative and determined if their experiences within the project were indeed a collaboration. It is interesting to note that most people defined collaboration as a group of people working toward a common goal. This closely matches the dictionary definition, "to work jointly with others especially in an intellectual endeavor; to cooperate with an agency of instrumentality with which one is not immediately connected" (Webster, 1979, p. 217). While we include the requirement that individuals or groups work together toward a common goal in our definition of collaboration, we also require that each participant in the collaboration derive benefit from the effort. In a true collaboration, then, the goals of the project must be widely known and accepted, and all the players must benefit as a result of their collaboration.

Types of Collaborations

Although there are many possible ways to characterize the kinds of collaborations within ALERT, we have divided them into two major types--intra- and intercampus collaborations. There are "within campus" partnerships at CSU and each of the NASA labs. At the CSU level, these occur among science faculty (mostly geologists), educational faculty and in some cases, social science faculty. These faculty are housed in different colleges on most campuses, and in many cases, ALERT was the genesis of their relationships. As ALERT expands on each campus more personnel become involved, thereby changing the dynamics of collaboration. At the

NASA labs, the intracampus collaborations were between their education outreach specialists and scientists.

In addition to these intracampus collaborations, there are also several possibilities for intercampus collaboration. Within the CSU, there are potential campus-to-campus collaborations. The CSU system is large and campuses tend to act in isolation. Even campuses which are centrally located have little formal contact. Through ALERT, they have begun working together.

There are also CSU-NASA institution-to-institution collaborations. The missions and goals of the CSU system and NASA are very different. As a result, their organizations, values and culture vary. This project has brought together partners form these different structures to work towards the common goal of better preparation for K-12 teachers.

We will examine each type of collaboration, as we describe their particular characteristics, identify impediments to and evidence of success, and outline lessons learned. What we have learned thus far in Project ALERT regarding intracampus and intercampus collaboration can contribute to our general understanding of the influences at work in establishing such collaborations, as well as inform future decisions about them.

Intra-organization collaborations, CSUs

Collaborations based on relationships established previous to the start of ALERT

Within the "intra-organization" category of collaborations, there were distinct differences between CSUs whose interdisciplinary teams had a previous relationship before the start of ALERT, and those whose interdisciplinary teams were initiated with the advent of ALERT. For example, on some campuses the educator was in the same college as the scientist. In these cases, if the team members didn't already have an existing relationship, they at least had a nodding acquaintance prior to project involvement, usually knowing at least what the other did. Where there existed a previous relationship at the time of the formation of ALERT, the team members had already established personal connections and mutual respect for each other's expertise. These relationships turned out to be an important element underlying the successful collaboration of these CSU teams in at least two ways: a shared professional interest on the part of the collaborators, and self-selection by the collaborators.

A shared professional interest on the part of the collaborators

The shared professional interest on the part of the CSU collaborators with personal relationships prior to ALERT--in this case, the improvement of science content knowledge on the part of future teachers--meant they already had a common ground upon which to focus their energies. This became very important, since it directed the overall reform efforts with which the collaborators were and still are engaged. In plain words, they didn't have to have a discussion about what it was that they want to work on. This is not to say that the common vision was flushed out in all of its details at the very beginning of the collaboration, but having established agreement on the basic direction of efforts meant that energy expended would be more likely to move in the desired direction.

Because the collaborators already had consensus about where they wanted to go, they were able to move directly into the planning stages of their work. One of the collaborators from a CSU team that had a relationship already in place at the time of ALERT states:

> The collaboration that has occurred on our campus between the College of Math and Science and the College of Education has taken shape over the last 3-4 years, and has centered around the revision of two key science courses that Liberal Studies pre-education majors are required to take. The collaboration began via the personal relationships we developed beginning with university committee work. On this particular committee--the Liberal Studies Program Committee--, there were faculty from all different colleges and departments, some of whom had never even heard of each other, let

> alone met. Through the work of the committee, we got to know each other fairly well, and we certainly were able to identify faculty that shared like understandings of what needed to be done. Most of us realized--or at least I realized--that we would not be able to achieve our goals without working together, and so it helped us to form teams that we thought we would be able to work with. Over time, we introduced each other to other interested members of our respective colleges, who then joined forces with us. By the time ALERT came along, we had already been working together for at least 3 semesters. (interview data with B. Hawkins CSU Northridge, 1999)

What is clear is that the collaborators had gotten to know what each other's views were, and had been able to come together in a way that was mutually beneficial. With that well-established connection as the backdrop, the members of this collaborative team were ready "to hit the floor running" when ALERT came along.

Self-selection by the collaborators

The agreement of the collaborators on the issues they wished to pursue relates closely to the fact that the collaborators themselves chose to participate in working on the commonly identified reform efforts. That is, because they themselves had chosen to participate in the reform efforts, the collaborators were more apt to engage themselves in the work over the long haul. The "long haul" would make demands on them that could not necessarily be foreseen at the beginning, and the element of self selection helped to ensure the necessary commitment. For these people, ALERT was seen as a vehicle to make happen what they wanted to happen, and so they were immediately willing to participate. For them, it was almost as if they had chosen ALERT--before it even existed. In the words of one of the team members from Geology,

> When ALERT came along, we were looking for a way to make our work go on, to be able to take the long-term view. Everything we had done up until then had been dependent on short term grants, and we knew we needed a way of continuing our work. So, we were ready for ALERT, and we were going to make sure that we would join the group if at all possible. Actually, we jumped at he chance to be involved; it seemed like an answer to prayers. (personal conversations, G. Simila, CSU Northridge, 1999).

The importance of self selection is reiterated when considering one of the problems that has begun to surface. The effort to interest other faculty to participate in ALERT has not been as successful as the original teams had hoped it would be, and this is true for both colleges of science and education. One reason for this is, of course, that other faculty have "self-selected" into other projects, and do not feel able to make another commitment, even if they consider the cause to be worthy. Another reason, however, appears to be related to the common vision discussion above. The work of the ALERT team members has been viewed by other faculty with everything from enthusiastic to quiet interest and support, to a "wait and see" attitude, to "benign neglect", to open skepticism. What is clear is that it is not as easy to enlist the participation of these other faculty members, and this has shifted the posture from one of self-selection to that of recruitment. This very shift serves to highlight the power that self-selection brings into the mix of successful collaboration. As some members have stated,

> What we need to do is to recruit in a way that the people we are recruiting decide that they want to be included. It's like we need to make it so they self-select to join with us (interview data G. Simila & B. Hawkins, CSU Northridge, 1999).

Collaborations formed only at the start of ALERT

Several intracampus partners hail from two different colleges. In these situations it was common for faculty to be meeting for the first time as a result of ALERT. These situations required more time at the start of the project to learn what each other did. Scientists did not know the language and job of educators. It was common to hear questions asking for definitions of terms (e.g., pedagogy, methods, assessment, standards-based instruction). On the other hand, the educators--generalists in particular--were often unfamiliar with the science content and felt intimidated by the scientists. Until a comfort level and degree of trust had been built, they didn't feel comfortable asking lots of questions. As is expected, partnerships that had no previous relationship implemented change more slowly.

These new relationships tended to fall into two categories: forced or forged. When the partners did not have a previous connection, the result was either a forced relationship, or one that was forged. Just as arranged marriages can work, some of the new partnerships between people who didn't know each other previously worked out to be productive. More often, however, the relationships became forced, a partnership in name only. In some cases one partner was reluctantly brought into the project. In contrast to those who self-selected into ALERT, the fact that they were recruited or pressured to join often made them recalcitrant. They are partners on paper, but not in reality. This lack of self-selection resulted in a "lone ranger" model of implementation for these partnerships. The active team member may make changes in his own classes, but without the benefit of the expertise of his less active partner. For example, the educator "lone ranger" does not have his less active science faculty partner's expert content input and knowledge. Likewise, the science "lone ranger" does not his less active educator partner's expert pedagogical input and knowledge. On the one hand, the "lone rangers" are to be complimented for attempting to implement the project, but they are bound to be less successful and have less campus-wide impact than their peers working together in a true partnership. Another concern inherent to the "lone ranger" implementation of collaboration is that all the impetus for change resides in one person. If that person were to leave the campus or the project, the change would leave with him, and without partnerships and multiple participants, the change is not likely to be systemic.

Intra-organization collaborations, JPL

The influence of ALERT among the participants at JPL is not easily described. For the participants in ALERT from Educational Outreach at JPL, the decision to become involved was closely connected to the demands of their positions. Not only could they provide assistance to the CSU members of ALERT, they could also receive help in carrying out the goals of their work, which is related to NASA's mission for Earth Systems Science Education (ESSE). It is within this area of Educational Outreach at JPL that we have seen the influence of ALERT most clearly.

The intra-organizational effects of participation in ALERT on the educational outreach collaborators at JPL seem to have their origin in the inter-collaborative efforts of ALERT. The collaboration with the CSU educators, from both education and science content areas, has helped the educational outreach participants to rethink their ideas of the nature of education, and this in turn has influenced the ways in which they have set up and prioritized their internal goals. In general, they have replaced earlier ideas to attach their efforts to various missions by means of specifically describing and explaining the mission and/or features of the mission, to one of examining how the missions can help to uncover and support the earth systems science curriculum, K-16. They have been very open to and frank about wanting the input of educators in their endeavors, and ALERT has given them a vehicle to receive this input and then re-examine their approach to educational outreach. In response to the request for "input on the collaborations that have occurred (or are occurring) within JPL as a result of participation in ALERT", one educational outreach participant from JPL writes:

> I think where JPL has been influenced the most is in the understanding of what education is, and what constitutes useful and good education. Previously we had been going down the road of 'teaching projects' ('Here is X mission, it looks at this, it weighs this much, and here are some fun people. . . ') Now we look at what concepts can be taught in schools and how we fit in ('How do we learn about geology? 'What things do we need to know, and how do we measure them? What makes those measurements? What are the results? . . .') There has been a JPL systemic effect. I think we have the possibility of going to more of an Earth curriculum instead of mission curricula, but it's going to be a stretch, and going to take more than ALERT. Another component is learning how to make Earth science a part of 'everyday' learning, and not just an enrichment module, and about identifying pieces (e.g., math, [other] sciences, etc.) that can illustrate Earth

> science to the Educational Affairs Office here. (e-mail correspondence, M. Syvertson, JPL, November 19, 1999)

This comment was given after one complete year of inter-organization meetings, and at the end of the second summer of ALERT fellowships . Compare it with one given earlier, by a different Educational Outreach ALERT participant from JPL ,after the first summer of ALERT fellowships and only one or two joint meetings:

> . . . We have determined, through the ALERT Project to invest in each other's future by our cooperative efforts to learn from each other. [. . .] In retrospect, it has occurred to me, how important it is for JPL project managers to familiarize themselves with the processes that take place in attempts to meet sometimes impossible or unrealistic deadlines. Most project managers are driven by launch schedules, and look at schedules linearly, which does not directly involve them in the process (i.e., of educational project development associated with the overall mission project) (Syverston, JPL, 1999).

This earlier comment was presented as part of a summary report that detailed the summer fellowship experience from the point of view of a JPL colleague in Educational Outreach who worked with a CSU ALERT participant. When compared to the comments presented earlier, it offers a glimpse of the distance that Educational Outreach at JPL has moved since the inception of ALERT. To be sure, the joint, monthly meetings and the summer fellowships have brought both constituencies into working contact, but the effect that this contact has had on how the Educational Outreach at JPL views its own work is reflected in the comparison of the statements. Taken together, they seem to indicate that one of the by-products for Educational Outreach at JPL is an ever-deeper understanding of the nature and demands of education, and that this understanding is having an impact on how Educational Outreach conceives of its role at JPL.

Intercampus Collaborations

CSU to CSU/NASA (or NASA to NASA/CSU) Collaborations

The same sorts of patterns emerge for successful intercampus collaborations that were seen in intra-campus collaborations. Time for relationship building; previous relationships and common goals; and self selection (the option to participate in external collaborations) were predicting factors for success. We have divided the intercampus collaborations into those between groups and those between individuals. This division is somewhat arbitrary as group collaborations require individuals to take the lead in getting them started.

Intercampus Collaborations Between Groups

There were three possibilities: JPL - Ames, NASA-CSU and CSU-CSU. There were regular regional meetings of CSU and NASA participants in both the north and the south. These monthly meetings were hosted by individual campuses on a rotating basis. They provided regional opportunities for members of the groups to share progress, clarify common goals, devise plans to achieve those goals, and begin developing a method of evaluating progress. The latter agenda item is on-going and requires the group to act as one. Project goals and the role of participants functioning within the realm of a group are highlighted when participants are forced to evaluate their contributions. The regional meetings allow for the cyclical process of goal setting and project evaluation. Participants examine goals, reflect on who they are and how to reach the goals, determine progress/success and re-evaluate goals. With each iteration the goals become more focused and the group's identity, and individual contributions, more defined.

Project meetings are another venue for this type of collaboration. The project meetings are bi-annual and include all participants from the northern and southern regions. These meetings are less frequent which has made north-south collaborations occur more slowly. However, effective north-south collaborations do occur between members of the steering committee.

The steering committee is comprised of one CSU faculty member from the north, and one from the south, and leaders from JPL and Ames. This group has weekly teleconferences and several face-to-face meetings. They serve as a model for the project regarding collaboration, shared decision making and leadership.

Participants are seeing the value of intercampus collaboration. It has allowed for shared resources and increased awareness of opportunities. For example, as a result of ALERT, classes from one CSU will visit a teaching resource at another CSU. During summer fellowships at the NASA labs, CSU faculty met informally with NASA faculty to see how their work can support to each other's. NASA to NASA impact is seen in the following statement from a NASA Education Outreach leader. "You'd be surprised, but the Ames-JPL part is really, really important. We met last week to talk about a major federal initiative funding opportunity. I wouldn't have had that contact without ALERT." (e-mail correspondence Marguerite Syvertson, November 19, 1999).

Each campus has developed a project web site where they can showcase modules, course innovations, and educational products. See the project home page for listing of innovations at http://projectalert.nasa.gov/index.html. This has allowed for another level of sharing and collaboration. Project members provide feedback to each other on products developed and used. A project wide mode of assessing modules and web sites is being developed. A result of the common repository for products is less duplication and more sharing of efforts.

Another way intercampus collaboration will be enhanced is via the project assessment. Teams comprised of scientists and educators from different campuses will visit all participants as part of the on-going assessment of the project. This will help forge new partnerships as the visiting team will travel together and share the common evaluation task. This aspect of the collaboration will begin spring 2000.

Intercampus Collaborations Between Individuals

Intercampus collaborations that are strongest have sprung up between individuals. Lone rangers have been able to team up with a partner at a different campus, often with their NASA partners. Educators from different campuses have collaborated on research projects, given suggestions for course changes, and provided valuable feedback on campus activities. Professors have shared successful teaching ideas, labs and demonstrations. These partnerships were not forced. The partnerships resulted from friendships, common professional challenges, and educational goals.

CSU faculty who spent the summer at a NASA lab built strong ties with their NASA partners. In several cases the relationship has provided the catalyst for other endeavors. For example, several grant proposals between CSU and NASA faculty were written. These grants are substantively different than ALERT and, if funded, ensure that the relationships will continue beyond the ALERT funding cycle. NASA & CSU summer relationships have developed into professional relationships. When a scientist has an education question (or a science question) to ask there is a specific person to contact, and vice versa. Data sets are shared, curriculum materials are field tested, and general questions answered.

Conclusions and Implications

We have learned many things in the first 1.5 years of Project ALERT regarding collaboration and implementation of the project. Many of our conclusions are not new. The change literature and professional development literature cite findings similar to ours (e.g. Darling-Hammone, 1996; Fullan, 1991; Lieberman, 1995; Schmoker, 1996). Having participants who want to be part of the project helps. These people are more actively involved in the project and contribute more. This is consistent with findings that volunteers tend to contribute more, or be more involved with professional development projects. The importance of time, and the fact that change is slow cannot be over emphasized. Time was needed for participants to fully understand, and buy into, project goals. Time was also spent revisiting project goals and finding ways to demonstrate progress towards them. Time was needed for participants to understand their colleagues and the culture their colleagues work in. Time was needed for participants to get to know each other so that trust and respect could develop. The understanding that each participant brings an area of expertise and that everyone can learn from each other is important.

Fostering that understanding was important. It was done by: having individuals do short presentations for the group; having small working groups during meetings; having meetings on each of the different campuses; treating people's ignorance as a learning opportunity instead of ignoring, belittling or dismissing it.

The factors that contributed to collaborations in ALERT as well as those that inhibited collaboration are found in Table 1.

Next Steps - Keeping the Collaboration Alive

Progress has been made but it must continue if ALERT is to be in place after funding ends. Hallowell (1998) reported that ALERT was an exciting collaboration in search of a structure. A structure has emerged and time will tell if it is able to support and sustain the changes that have taken place.

As the second half of the funding begins it is important to find ways that will make the changes sustainable. This will mean that new participants on each campus must be brought in. Changes to courses, not just sections of courses, must be negotiated. If needed, alternative funding sources must be found to keep the regularly scheduled meetings occurring. Perhaps as more people on each campus get involved the regularly scheduled meetings will occur more locally (on individual campuses with their team) along with less frequent regional meetings. It is important to find ways to demonstrate the changes that have occurred. At this point we have educational modules and websites developed but there is no data that shows how often those sites are being used, the effects of the sites on student learning and attitudes. A logical next step would include some data collection in those areas.

Table 1.

Features that promote and inhibit collaboration

Stepping Stones to Collaboration	Stumbling Blocks to Collaboration
• Meetings - regularly scheduled regional meetings and joint meetings • Rotating meetings so each campus serves as host (home court advantage is shared) • Time - to build relationships - to visit each other's classes - to understand project - to become full partner in the project • willing participants and partnerships • Opportunity for in-depth, meaningful research and interaction (summer fellowships) • Understanding and respect for the different cultures that participants have (education versus science, CSU versus NASA) • Treating participants as professionals - sense of group identity, a sense of belonging - allowing participants to showcase their expertise - food at meetings • Good leadership who share a common vision • Participants with previous working relationships were able to move ahead faster	• Insufficient meetings - either not enough time at meetings, less effective agenda time in meetings for meaningful interactions (too much time spent on reporting) or not enough meetings • Forced relationships • Imposed goals (participants' sense that they don't have a voice in project goals/direction) • Mismatch between group and participant goals • Lack of time for relationship building and for implementation • Perception that this is a *scientists* project (based on composition of the steering committee) • Lack of understanding of the cultures represented in the project • Lack of respect for participants (and/or their area of expertise)

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M.A.T. INTERNS' VIEWS OF SCIENTISTS

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Who is a scientist? What does a scientist do? An online version of Compton's encyclopedia describes a scientist as an individual who engages in scientific activities to know about the world and various phenomena (Mitchell, 1998). S/he uses the scientific process to understand how living or inanimate things behave the way they do. This endeavor may be undertaken for the sake of learning, to improve individuals' daily lives, or to preserve nature.

In this paper, the researcher sought to understand elementary preservice teachers' images of scientists, particularly those who were enrolled in a Masters of Arts in Teaching (M.A.T.) degree program. Three questions provided the focus of this study. What images do elementary M.A.T. interns have of scientists at the beginning and end of a science methods course? What, if any, changes have they made in their perceptions at the end of the course? To what sources do they attribute their images of scientists? The following sections of this paper will provide background information of the preservice teachers, the instrument used to generate the data, and what the researcher learned from the preservice teachers' perceptions.

Background

For more than 50 years, several education reform efforts have sought to improve science teaching and learning. Since the late 1980's, the role of constructivism in science education has received an increasing amount of attention. Constructivism may mean different things to different people (O'Laughlin, 1992; Wheatley, 1991). Therefore, O'Laughlin (1992) cautions against using the term indiscriminately. Also, Tobin (1993) has edited a book in which there are descriptions of various constructivism discourses that have been introduced to the science education community. For example, von Glasersfeld (1993) drew distinctions between trivial and radical constructivism, viewing both as two ways of constructing knowledge. Cobern's (1993) description of contextual constructivism focused on the cultural background of the learner. Meanwhile, O'Laughlin (1992) coined the term "emancipatory constructivism" within the context of power relations. While there are varying emphases on personal, cultural, and historical issues, the perspectives contain common characteristics. In a generic sense, constructivism features:

- a learner who has preconceived notions and ideas about the world and its events;
- instructional strategies that provide opportunities for active learning; and
- attempts to relate to a learner's background or to consider preconceived knowledge.

Within the context of the science classroom, constructivists state that authentic learning results from the learner's active thinking, manipulation and interaction with ideas and objects to facilitate understanding (Arons, 1989; McDermott, 1991; von Glasersfeld, 1989; Wheatley, 1991). Therefore, knowledge is always contextual and personal (O' Laughlin, 1992; Tobin & Tippins, 1993; von Glasersfeld, 1993; Wheatley, 1991). Information that is obtained through experiential processes is assimilated within the learner's existing cognitive schema. Inherent in the acquisition of knowledge, the learner develops the ability to interpret and apply knowledge to situations outside the context in which it was initially acquired (McDermott, 1991; Wheatley, 1991).

In agreement with constructivism principles, the National Science Education Standards (National Research Council [NRC], 1996) advocates instruction that includes a wide range of activities, including those in which students seek answers to questions they pose. In doing so, the students' investigation of natural world phenomena is not unlike methods used by scientists in the "real world" (Carin, 1997; NRC, 1996). Dealing with students' perceptions of scientists and the work that they do may assist them in making real world connections (Carin, 1997). The classroom teacher plays an important role in making these connections. Also, teachers are largely responsible for establishing and maintaining learning environments that may perpetuate or change students' views of scientists (Mason, Kahle & Gardner, 1991). Furthermore, preservice teachers are learners who bring personal experiences and perceptions to their teacher preparation courses. Therefore, it is appropriate for science and teacher educators to address preservice teachers' views of scientists.

Data Collection and Analysis

Preservice Teacher Demographics

The participants in this study were interns who enrolled in either the Early Childhood Education (ECE) or Elementary Education (ELE) M.A.T. degree program at an NCATE- accredited institution in the Southeast. The ECE interns were interested in teaching children in preschool settings or at the kindergarten- third grade levels. The ELE interns were interested in working with older children (grades 1-8). Only 5 of the ELE interns had a particular interest in teaching middle school students. As shown in Table 1 there were almost equal numbers of 5th year and Career Changer interns.

Table 1:

Preservice Teacher Characteristics

	5th Year (n)	Career Changers	Female (n)	Male (n)
Early Childhood	4	5	8	1
Elementary	10	10	17	3

Preservice teachers who successfully completed any undergraduate degree program at this institution and its 18 hour Education Minor of program were considered as 5th year interns. Also, the 5th year students enrolled in the M.A.T. program immediately after they earned their baccalaureate degree. On the other hand, career changers were generally older individuals who earned a bachelor's degree or had a career for at least 6 months before their enrollment in the M.A.T. program. One Career Changer was an African American female. A 5th year intern was a Pacific Islander.

Administration of DAST

The Draw-A-Scientist-Test (DAST) has been used to assess students' views on science and scientists. For example, Barman (1996) administered DAST to elementary students to probe their perceptions of who does science under specified conditions. Hill & Wheeler (1991) combined the use of DAST to investigate precollege students' ideas about science, scientists, and technology. Mason, Kahle, & Gardner (1991) used this instrument to study gender differences and the marginalization of girls in high school biology classrooms. To a lessor extent, researchers have used DAST to study views preservice teachers have on science and science teaching. In one case, Rosenthal (1993) administered the DAST to 76 liberal studies majors who planned to become elementary school teachers and 90 biology majors.

The researcher used the DAST-C with his M.A.T. preservice teachers in a similar manner. The rationale for doing so was twofold: (a) to provide them with an opportunity to critique their stereotypes that may be passed on to their future students and (b) to introduce them to an instrument that might help them investigate their future students' preconceptions of scientists and their work.

During the first and last class sessions, the researcher provided his students with a blank piece of paper and instructed them to draw a scientist at work, similar to administration procedures used in the Mason et al. (1991) and the Rosenthal (1993) studies. No other clues were provided. On the back of each drawing, the students were instructed to write their names, a brief caption that explained the context of the drawing and the source(s) that contributed to their image of the scientist(s) drawn. Although each intern was required to draw a scientist at work, the course instructor clearly indicated that the assignment would not be graded. None of the interns were required to participate in the study. Throughout the science methods course, the researcher provided opportunities for his students to conduct scientific investigations, apply science process skills, search the internet for developmentally appropriate activities, read and discuss professional literature regarding science teaching and learning issues, and to design lesson plans for students in elementary grades. The science methods text written by Howe & Jones (1998) provided the basis for most of activities, discussions, and assignments.

Data Analysis

During the analysis, NUDIST software was used to help manage and categorize the data. Since many of the drawings contained very little text, but rich information, the descriptions of the illustrations were entered as text files, using the off-line document procedures (Qualitative Solutions and Research [QSR], 1995). The categories were pre-established, using the classification scheme that Finson, Beaver, & Cramond (1995) developed and that Mason et al. (1991) implemented. As he imported these categories, the researcher entered them to a theoretical tree as nodes that served as the index system. The corresponding elements of the drawings were attached to these nodes. In addition, the interns' descriptions of sources that influenced their perceptions were analyzed, using the same procedures that were used to critique the content of the drawings. The relationships among the nodes were tracked in a tree diagram that reflected the theoretical framework of the study.

Results

At the Beginning of the Semester

At the end of the first class session, most of the interns (86.20%) drew traditional images of scientists, depicting individuals who worked alone and inside of a building. The following clues that suggested that the scientist worked indoors: desk or table, glassware that hung on the wall, a door in the background, and wall charts. Two interns (6.89%) drew scientists working outside. There were trees, grass, streams, or clouds that served as clues. Another intern drew two frames that depicted a scientist who worked outside and one who worked inside. In the remaining two drawings, the research was unable to determine where the scientist worked; the interns drew only the face of the scientists without any details of the environment. Only three interns drew a scientist who was working with at least one other person. A few representative drawings are included in Appendix A.

Most of the drawings portrayed traditional images of scientists. More than 41% (12) of the interns drew White males while more than 34% drew White females. After an analysis of the scientists' features, none of the scientists appeared to be a member of a racial minority. As is evident in the samples included in Appendix A, a non-White scientist was not drawn (i.e. images with broad noses, "kinky hair", dark skin, etc.). All of the images drawn appeared to have White features (pronounced noses, straight or curly hair, rounded eyes, pale skin, etc.).

As stated earlier, Finson et al (1995) identified eight characteristics that were identified as "traditional images" of scientists. In addition to the ones addressed in the previous two paragraphs, these views included indications of danger, presence of light bulbs, mythical stereotypes, and indications that the scientist was conducting an investigation under the cloak of secrecy. Using these criteria, the researcher of this study identified 3 drawings that contained only alternative images of scientists. Two of the illustrations, both drawn by ELE interns, depicted elementary students in a classroom observing objects. An ECE intern drew a woman working in her flowerbed. See her illustration in Appendix A.

With one exception, all of the interns drew pictures that contained at least one of the traditional characteristics that Finson et al (1995) identified. These drawings can be categorized into three general categories. In one category, the illustration was reminiscent of the "Hollywood" conception of a scientist at work. It consisted of a male who wore a wizard's hat or had unmanaged hair. In the most extreme case, the scientist has a "magical wand" in his hand. In the background, a comet streaked across the sky while an oddly shaped sun shone. There were test tubes and other glassware on the table or in the scientist's hand. In most cases, these containers were smoldering or bubbles appeared to emerge. Generally, only a few scientists wore lab coats; most of them wore "normal" clothes. One ECE intern admitted, "I suppose that my Hollywood scientist ('mad') conception influenced my picture the most. Compounded with that idea, [it resembles] a science teacher I once had."

There were a variety of factors that influenced what the interns drew. For example, the ECE intern who drew a woman working in her flowerbed admitted, " I like gardening and flowers; it's probably the only thing that I can draw". In addition, she described her science experiences to be negative one in the following quote.

> Nothing made sense or seemed to connect to anything else back then. I had absolutely no interest in animals or nature. It has only been in the last few years, outside of school, that I have been interested in science and nature, thanks to PBS, Discovery, TLC, etc. (ECE Intern).

A couple of interns sought to represent trends they had observed in society. For example, one female ECE intern indicated, "I chose to draw a woman [sic] scientist because women are now slowly being recognized in the field, also." Modern textbooks and popular media suggest that under-represented minorities are receiving an increasing amount of recognition in scientific endeavors. Perhaps these resources contributed to her image of a scientist. A few other interns indicated that their drawing ability was limited and that limitation influenced what they drew. In those cases, evidence that illustrated the negative impact of science learning experiences on their drawings was limited or nonexistent.

Another group, ECE and ELE interns had positive experiences with science learning. Generally, these experiences were associated with their active involvement in the learning process. For example, they remembered working in small lab settings, dissecting animals, conducting investigations at different levels of sophistication, and learning under the guidance of caring and personable teachers. As a result, a couple of interns drew themselves as scientists. An ELE intern elaborated on her view in the following quote,

> When I think of a scientist, I first think of the planets and our solar system. My picture shows me next to a telescope about to talk about our solar system and how to use a telescope.

In another category, a few of the interns drew more "serious" images of scientists at work. These drawings included at least one traditional representation of science, also. However, the individuals consisted of men or women who had well-kept hair and neat clothes. Generally, the scientist was pouring a liquid into a container or explaining a concept to an unseen audience. In most of the illustrations, the scientist was involved in or explaining a chemical investigation. The major distinction between this category and the previous one was that the scientists were "normal" people who were engaged in realistic activities. In a particular case, an ELE intern drew a male who wore glasses and was seated at a computer in a room that had a wall-mounted chart of a hurricane. Through the window, satellite dishes and mountains were visible (See Appendix A).

The sources that shaped these drawings varied. Regardless of the source of influence, personal experiences played a major role in what the interns drew. For example, an ECE intern who drew a "realistic" image of a scientist explained,

> I think of my father_ not exclusively, but he comes to mind. He was a chemical engineer and worked in the rubber industry, coming up with "recipes" for tires. He looked the part, wearing a pocket protector and glasses. He had infinite patience and curiosity.

Based on the data provided, the researcher could not determine what the intern meant by "he looked the part" or how the intern learned about this traditional perception. The majority of interns who drew "serious" scientists reflected on their high school or middle school experiences with chemistry. They drew scientists in chemical labs because they remembered those experiences in chemistry class best.

Images Drawn at the End of the Course

The images of scientists that the interns drew at the end of the course were significant different from the ones that they drew at the beginning of the semester. In the most extreme case, an ELE intern cut a large rectangular hole in his paper, forming a picture frame. In doing so, he sought to accommodate the many facial features and physical features that scientists have. During the drawing exercise, he instructed the researcher to view individuals involved in learning processes through his "picture frame" to understand his latest conception of scientists at work (See second drawing in Appendix B).

Most of the final drawings included children involved in science lessons or investigations. For example, one ELE intern attempted to reproduce a scenario from her practicum placement. The teacher was represented by a stick figure who stood at a desk at the front of the class. The students (also represented by stick figures) were grouped together, some of them with raised hands (See Appendix B). Another intern drew a similar picture. However, her illustration was based on her experiences in the methods class in which she helped the methods course instructor with two demonstrations. In the remaining 12 illustrations, the ECE and ELE interns drew precollege students taking nature walks or conducting investigations. In most (10) of these illustrations, the science investigations took place indoors.

At the beginning of the semester, the interns generally viewed science as a solitary endeavor. Conversely, they depicted scientists as sociable individuals at the conclusion of the course. With the exception of 5 illustrations, all of the interns drew individuals who were interacting with each other. In one case, the scientists were drawn in the same room working on different projects. In the other drawings, the scientists were working together or discussing an aspect of their work together.

Although there was a dramatic increase in the number of females drawn, the ethnicity of the scientists did not appear to change. All of the scientists appeared to have White features (long-haired women, fine noses, straight or curly hair, pale skin, etc.). None of the pictures contained individuals with almond-shaped eyes or dark complexions. In several instances, the interns drew "faceless" individuals in an effort to broadly represent what a scientist might look like. In the same illustrations, the stick figures wore no clothes to avoid pinpointing the sex of the individual(s). In two cases, 2 interns drew stick figures because they were apprehensive about their drawing ability.

At the end of the semester, 12 (approximately 42.9%) of the interns indicated that the course activities and/or discussions influenced their drawing. For example, several of the ECE interns singled out a Nature Walk activity. An intern stated, "The experience that influenced my drawing was the nature walk on the horseshoe" (ECE 5th year intern). The course instructor used this experience to model how teachers could use their surrounding environment to develop and reinforce observation and inference skills while focusing on seasonal changes. The ECE interns played the role of first or second grade students; they looked at various leaves, smelled the autumn air, and felt the texture of several objects. Upon returning from the walk, they discussed their experiences, as primary grade students might do and reflected, as preservice teachers, on what ways they mimicked "professional" scientists. The ELE interns participated in a different activity during the Nature walk. They did not specifically name a particular class activity that influenced their drawings. However, they felt that the Howe & Jones (1998) text and the methods course influenced their perceptions of scientists at work, as suggested by the following sample quote.

> Our textbook and this course [EDEL 744] influenced me to draw this picture. I have learned the importance of being cognizant of gender bias and its ramification (Elementary 5th Year Intern).

In a few other instances, 33% of all interns identified the practicum experiences as the source of their new perceptions. For example, one ELE intern explained,

> While teaching students, I've realized that anyone can be a scientist. Men and women have equal opportunity. Everyone acts like scientists each day as they move through their everyday world.

This intern completed her practicum in a classroom in which the students were frequently involved in scientific investigations. By nature of their placements, the other interns had varying experiences. Specifically, some were in elementary or primary classrooms in which science was integrated with other academic subjects at least twice a week and the mentor teacher encouraged students act as scientists. In other classrooms, science was taught in a more traditional manner, consisting of reading and discussing a science textbook and conducting a limited number of scientific investigations. Still others completed the first part of their internship in middle school language arts, math, or social studies classrooms.

There were two ELE interns who submitted perceptions that were similar to their initial ones. A Career Changer drew a male who was involved in landscaping activities, drawing from his previous occupational experiences. He felt that he was a scientist at the beginning and end of the course. The methods course activities appeared to confirm his belief. In the second case, an ELE 5th year intern drew multiple scenarios in which scientists were working. Her illustration included a wider variety of work situations than her first drawing. However, her undergraduate experiences in a science content course continued to have a strong influence on both drawings.

Final Reflections

The first research question focused on the images that early childhood (ECE) and elementary (ELE) M.A.T. interns have of scientists at the beginning and end of their science methods course. At the beginning of the science methods course, ECE and ELE interns generally perceived scientists as White males or females who engaged in a variety of scientific investigations. None of the drawings appeared to include scientists who were members of underrepresented minority groups. All of the scientist images were adults who worked alone, also. Scientists involved in chemical investigations were most common. Only 3 interns drew illustrations that contained alternative images of scientists.

Based on the images that the interns drew at the end of the semester, there were several modifications in their images of scientists. The biggest change featured the inclusion of children in classroom settings. Also, the interns had broader views of who does science. As a result, they drew several scenarios that portrayed individuals engaged in a variety of scientific activities. Most of the illustrations emphasized the social interactions among scientists; scientists were no longer perceived as individuals who worked in solitary confinement. While there was an increase in the number of female scientists, the racial identities of the individuals drawn remained unchanged. In some cases, blank faces and stick figures were deliberately drawn to avoid stereotyping. In fewer instances, these stick figures were the result of the interns' inability to draw people.

Finally, the researcher sought to identify to what sources the interns attributed their images of scientists. The media continue to feature "the mad scientist" image. However, the Discovery Channel, the Learning Channel, instructional TV programs, and other educational programs have provided more natural images of "ordinary" people who have chosen science professions. Overwhelmingly, the interns pointed to personal experiences in which they learned or taught science as major influences. These references corroborate with the work of constructivists who emphasize the need for active learning opportunities. Preservice teachers benefit from active engagement in learning how to teach science and develop less stereotypical images of scientists.

Finson, et al (1995) incorporated interviews to better understand the views of their research participants. In this study, the interns provided written comments about their drawings. Although the comments were insightful, they were limitation. For example, an African American male taught the science methods course. Yet, none of the interns drew him even though a couple of interns drew their former science teachers. Furthermore, none of the interns drew African American scientists. Since there were no interviews conducted, the reason for this omission is unknown to this researcher.

The interns incorporated various science methods course and school-based practicum experiences in their final drawings. A few ECE interns included the Nature Walk Activity in their final drawings. An ELE intern drew a demonstration lesson that was similar to the ones in which she assisted the methods course instructor. Other interns drew various scenarios in which scientists were conducting investigations, sharing information with others, or wondering. These drawings highlighted the diversity (in terms of age, sex, and science discipline) that exists among those who engage in scientific endeavors. This study underscores the importance of providing learning opportunities that may alter preservice teachers' perceptions of scientists. Science educators who seek to expand their interns' images of scientists must provide engaging experiences in which the preservice teachers critique their perceptions and explore alternative images. Science educators may not change their preservice teachers' image of scientists but should teach like they can.

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Appendix A: Samples of Images Drawn at the Beginning of the Semester

Appendix B: Samples of Images Drawn at the End of the Semester

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THE CULTURE OF TRADITIONAL PRESERVICE ELEMENTARY SCIENCE METHODS STUDENTS COMPARED TO THE CULTURE OF SCIENCE: A DILEMMA FOR TEACHER EDUCATORS

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The National Science Education Standards (NSES) indicate that (a) inquiry should be the central organizing theme when teaching science, (b) good science teaching should reflect the nature of science and its history, and (c) teaching science should result in meaningful learning (NRC,1996). Meaningful learning requires the integration of thinking, feeling, and acting (Novak,1998). The thinking, feeling, and acting patterns of preservice elementary teachers learning about science teaching were compared with the thinking, feeling and acting patterns that characterize scientists learning about the natural world in order to understand the difficulty the preservice teachers had learning to teach science that was consistent with the NSES.

The extant literature investigating negative attitudes towards science in traditional preservice elementary teachers and the literature on inquiry teaching consistent with the NSES (1996) set the context for this study. It has commonly been assumed that much of preservice elementary teachers' science anxiety is related to their own lack of success learning science in traditional didactic classrooms (Blosser, 1984; Koch, 1993 &1990; Mallow, 1986; Orlich, 1980). The advent of the NSES with its accent on inquiry, nature of science, and meaningful learning introduced other dimensions of science with potential to cause anxiety in preservice teachers of elementary science. “Prospective teachers who have not experienced the tone and substance of scientific inquiry in meaningful ways cannot be expected to catalyze in their students what the teachers themselves have never actually experienced” (Barnes & Spector, 1999 pg.1). The emerging field of implicit social cognition indicates actions like those needed for scientific inquiry are influenced by factors lying below the level of consciousness that profoundly influence people's decision-making and actions, including teaching decisions (Greenwald & Banaji, 1995).

Anthropologists label a learned pattern of thought, behavior, and communication "culture". Some of these patterns exist below the level of consciousness (Yelvington, 1999). All human cultures have many basic similarities because they fit, more or less, the basic needs and evolutionary history of humans (Wilson, 1998). There are some things for which humans are genetically prepared to learn and take only one trial to learn. Things for which humans are unprepared take a number of trials to learn. Others for which humans are contraprepared can only be learned with great difficulty (Seligman, 1970, 1971).

"Culture" is used herein to describe patterns evident in a group even though individuals come and go from the group. These patterns include values and assumptions; actions consistent with the values and assumptions; thinking, feeling, and action (learning patterns); and personality profiles. Personality is the propensity of an individual to behave or act in a certain way within social situations. The pattern of the personality profiles of the majority of people in a population is the dominant personality profile for the culture. Values and assumptions inherent in the development of scientific knowledge, commonly labeled nature of science (Lederman & Zeidler, 1987), combined with actions including communication are referred to as the "culture of science" herein.

The Study

This was an emergent design qualitative study in the tradition of symbolic interaction (Jacobs, 1987) that generated grounded theory (Strauss & Corbin, 1990). Two researchers examined five sections of a science methods course for preservice elementary teachers that were taught by the same instructor over a period of four years. The frustrations and anxieties students expressed in response to the instructor modeling inquiry consistent with the NSES was the stimulus for the focal question of this study, "What explains the difficulty many students encountered in these elementary methods classes and their resistance to inquiry teaching?"

Course Context

The course used inquiry as the approach to teaching and was structured as an inquiry into the question, "What characterizes science teaching in an elementary school that is consistent with national standards?" Events and interactions were designed to model habits of mind, decision-making, and actions inherent in doing science. Learners had multiple sources from which to collect data to construct ideas. They included readings in a textbook, class packet, and recommended books; the Internet; site explorations in the community; video visits to elementary classrooms; interviews with classroom teachers and scientists; small group and large group interactions in class; and team meetings outside of class. Ethical traditions of science (NRC, 1996) guided the way the course was conducted.

Respondents

The first two classes studied were taught during the same semester. Participants in one were 31 traditional undergraduates who came to college directly from high school and four nontraditional students who were changing careers. Eighteen learners in the second class were nontraditional students who were concurrently teachers' aides for special education in schools. They were required to take the science methods course as part of a teacher certification program in special education. Much of that class was delivered through two-way audio and two-way video from a distance. The third class was composed of 29 traditional students. The fourth class of 29 students included 20 special education teachers who had five to ten years of school experience co-teaching with regular elementary teachers. They were seeking certification to have their own classes in elementary schools. In addition, there were five students who were second career people and four traditional students. The fifth class had 30 students. Twenty-six were traditional and four were nontraditional students who were changing careers.

It may be noteworthy that the special education program at this university is cast in the holistic paradigm, therefore, the paradigm used in the science methods classes was familiar to the most of the nontraditional special education students in the classes studied. They were used to using scientific habits of mind, such as gathering data about a student and making decisions based on those data. They understood the need to be responsive to a student's prior knowledge. They were individual oriented rather than oriented to crowd control. They seemed to be comfortable with multiple perspectives. The other career changing students appeared to have had experience with the holistic paradigm from being in the business world. They too appeared to have fewer cultural differences to deal with in these methods classes than the traditional students.

Data Sources

Data sources for this study included classroom observations throughout each course and focus group and exit interviews conducted by the instructor, students' reflective journals, and artifacts from other student assignments.

Data Analysis

One researcher, the instructor, collected and simultaneously analyzed the data from each class using the constant comparative method until emergent categories and relationships among them within each class' data reached theoretical saturation (Glaser & Strauss, 1967). Then each class was compared to the other classes for consistencies in the categories and relationships among them across the classes. Member checking (Gall, Borg, Gall, 1996) of emergent categories and their relationships was done with individuals and small groups of students within each class in the last quarter of each course and during exit interviews. After the first two classes, the emerging categories were presented in a session at a National Science Teachers Association conference. Session participants said they identified with the emerging categories because of their own experiences teaching preservice elementary teachers.

The concept of culture was later tested as a way to relate the multitude of seemingly disparate categories inhibiting students learning through open-ended inquiry. Emergent categories that are part of culture for which data existed included the values, assumptions, beliefs, personality profiles, and actions that were dominant in the group. An image of the culture of the traditional preservice elementary teachers, grounded in the data, emerged.

At the end of the fourth year the second researcher, an experimental psychologist familiar with science education reform, reviewed the emergent description of the culture to date and the data the first researcher used to support the interpretation. Together, both researchers compared the emergent culture to the culture of science. They used five theoretical frameworks as lenses to analyze the data: (a) the ethics of science presented in the NSES (NRC, 1996), (b) the nature of science as revealed in science teaching (McComas, 1998; NRC, 1996), (c) the biological evolution of "curiosity" as a basis for science (Spector, Strong, & LaPorta, 1998), (d) social psychological theory relating to need for achievement and fear of failure (McClelland, 1985), and (e) preferred style of social action (Lowry, 1989). (Need for achievement and fear of failure were not formally measured, but emerged as a useful theoretical framework for understanding the findings.)

The instructor used the ethics of science, the nature of science in science teaching, and the preferred style of social action as the theoretical frameworks to explain her findings. The second researcher used the biological evolution of curiosity as a basis for science and theory from social psychology to frame his analysis. Together, both researchers triangulated the interpretations from each of the five theoretical frameworks to generate the emergent grounded theory.

Findings

The culture (and subsequent worldview) of the majority of traditional students in these preservice elementary methods classes was not consistent with the culture of science. It appeared to be the antithesis of the culture of science. This conflict of cultures existed in varying degrees for individuals in all the classes studied. When a majority of the students in the class were traditional preservice elementary teachers, their culture dominated class interactions and set the tone for the class. Nontraditional students in all the classes usually provided negative cases that supported the emergent theory. The degree to which both traditional and nontraditional students were bound to the dominant student culture influenced the extent to which they were willing to test thinking, feeling, and acting consistent with the culture of science, and their subsequent success in the course.

Sample episodes from the database laced with quotations from traditional students, nontraditional students, and researchers' interpretations that provided insight into the conflict of cultures are described below. Evidence from traditional students, who late in the course began to test and accept the culture of science and see its benefits, is also included. Analytical frameworks comparing students' culture to the culture of science follow beginning with a description of the biological evolution of the neurological/hormonal instincts labeled "curiosity" and "safety seeking" that was used as a lens to interpret the data. A table is then presented illustrating three other analytical frameworks to compare the culture of science to the culture of the traditional preservice elementary teachers. The first section of the table uses the ethical traditions, as noted in the NSES, that are part of the culture of science. The second section of the table uses the nature of science in science teaching and learning. The third section of the table uses the profiles of the need for achievement and fear of failure compatible with science for the comparison. Comments from an inventory of people's preferred styles of social interaction used for analysis follow the table. The emergent grounded theory, its implications for science teacher educators, and questions for future research are presented in the conclusion section.

Sample Data and Interpretations

Resistance to "Doing Science" as a Way of Knowing

The concept of doing an investigation and gathering data from multiple sources to induce their own explanations for a phenomenon as a way of learning was foreign to most of the preservice students. Science as a way of knowing was also foreign to them. When they noticed a pattern relating the same idea in several sources but in different contexts, they labeled the sources "redundant". "Did you know the same topic is in another article?" "Why do we have to read about the same thing in different articles?" The value of multiple perspectives in constructing personal knowledge was not understood, nor was the iterative nature of scientific exploration. "Why don't you just tell it to us? Why do we have to find it out for ourselves from different places?" The fact that they were engaging in, and practicing skills involved in the process of doing science was not valued, even though the instructor was explicit about its value.

Tolerance for Ambiguity

A sequence of probing questions was frequently used as a means for coaching learners in ways to construct their own answers to their questions. Exasperation was a common response to the questioning. It was expressed in these ways: "When we ask you a question, why do you answer with a question? Why can't you just give us the answer!" "We don't have to know why. Just give us the right way to do it!" Still another response was "When I ask a question, I sometimes out of shear laziness, want it answered so I don't have to think. I know it sounds terrible, but not having a direct question answered all the time can be frustrating." At the end of the course a student reflected "We get so focused on coming up with the right answer, we deprive ourselves of learning the process of science."

Need for Achievement

When working in small groups doing closed-ended laboratory activities selected by the students from the Internet, most traditional students did the activities as prescribed and stopped. Not doing any more than is required is rewarding for people with a low need for achievement, in contrast to high need achievers for whom the process of achieving is reinforcing (McClelland, 1985; Murray, 1935). The nontraditional students, reminiscent of high need achievers, most often invented a variety of permutations and tested them until the time for doing the activity expired.

Resistance to Ethical Traditions

The problems students encountered with the ethical traditions of skepticism, respecting rules of evidence, making work public, and being open to criticism noted in the NSES surfaced whenever students were asked to identify the evidence and logic they used to make a decision or take an action. Most traditional students reacted more negatively than did most of the nontraditional students. This was the case regardless of whether the questioner was another student or the instructor. Some examples follow.

Students' Skepticism and Rules of Evidence. When doing an activity in small groups, students found they often did not agree with each other's observations or interpretations. The dialog in which they questioned each other's statements exploring why they differed was described this way: "All we did was argue!" It was interpreted as conflict and negative.

> I don't understand how each class has to turn into a debate. There are so many comments made that I don't agree with, but I feel that there is no point in adding my opinion because the debate will never end. ... I am not taking this class to hear debates, but I am here to learn about elementary science.

Students' Criticism. When reporting to the class on an exploration of the zoo as a place to take children, a student stated: "The next area was not any place the girls would want to go, nor would I take girls. It would just be of interest to some boys, because it was filled with snakes and other reptiles." One classmate pointed out the need to give girls the same opportunities as boys. Others chastised her privately: "You were right, but you should not have said anything!"

Instructor's Skepticism and Rules of Evidence. The instructor's usual procedure was to use questions as a tool to find out how rules of evidence were followed whenever students reported outcomes of a task done either in class or outside of class. She was deliberate and explicit about not making value judgement statements in response to students' reports of outcomes. One student equated the instructor's procedure to what she read in an article on conceptual change and perceived it to be positive. She said of the teacher in the article "She is trying to teach them to realize how they came to such conclusions." Other students, however, perceived the questioning negatively. When asked to analyze how the class modeled characteristics of science teaching consistent with the NSES, a student wrote, "After we would finish our experiments or projects in class you always hound us for answers to questions." A second student wrote, "… Each time you had us explain our project, you kept on with the questions about why and why not and what questions did it raise. This made me nervous, and not wanting to talk out in class." One group presented their lesson to the class and a student wrote in her journal that she perceived the questions to be "criticizing and humiliating" … "being on trial for having done something wrong." Still another wrote:

> I did not realize how teacher centered this activity was until you pointed it out (by asking questions to elicit evidence and reasoning used). … I felt put down because we did not create the learning experience you wanted. I don't think that was an appropriate way to broaden people's thoughts about certain things. I think that it just makes people upset and makes them feel like failures.

Skepticism and confrontation, so much a part of science, were not acceptable in these students' culture. By contrast, nontraditional students typically perceived the questioning and related processes used in the class this way: "I know that whenever I contribute to our class discussions, it is going to be accepted. It is my perspective. There is no right or wrong in that. Having that feeling allows me to speak freely." "We know that judgement statements affect risk-taking in a negative way. By not using these types of statements, … (the instructor) has contributed to a learning environment in which I feel safe expressing my feelings." These nontraditional students interpreted the questioning episodes as opportunities to put their perspectives on the table and explore a variety of ideas, while the traditional preservice students interpreted those episodes as focusing on being right or wrong.

Evidence and Its Use. Other specific contrasts in culture were evident in answers to the following two questions: (a) What was accepted as evidence? (b) What did one do with evidence that was deemed acceptable? In science, the extant literature base derived from research that has been refereed is a form of acceptable evidence. One is expected to use acceptable evidence as the basis for decision-making and action. In the dominant student culture, evidence from personal experience and its match to prior beliefs were used as criteria for acceptable evidence. The latter was preferred to the research evidence as a basis for decision making and acting. They made the fallacy of personalization their basis for action. Students often did not act on the evidence they collected from the research base they encountered in the course.

For example, the instructor and the textbook were explicit that student centered, open-ended learning opportunities were the desired state for science teaching. At the end of the semester, a student wrote the following in her journal after her team presented a totally teacher centered approach to the performance assessment task in which they were to describe how they would use a community site they explored with school children:

> … direction wasn't clear on what instructor wants. There were not specific indicators that we were supposed to bring out the student centered activity. I know that was the focus of the course and text, however, the class believed that science teaching shouldn't always have to be student centered in order to be effective.

Knowing and Acting. Part way through the course the following dialog occurred in one class: A student asked, "Why are we learning about teacher centered and student centered teaching in here? We already learned that in other classes. This is supposed to be about science methods." Some others in the class agreed with these comments.

The instructor said,

> If you already know the difference between the two, and you know that student centered is the desirable orientation, then why when I asked you to select a science activity from the Internet to do with your group did you all choose teacher centered activities to do? …
>
> Why when I gave you a teacher guided discovery activity to analyze and improve, did so many of you make it more teacher controlled than it already was, instead of making it more open-ended with more opportunity for the student to make decisions about what to do?

Most students said, "I don't know". One response to the Internet assignment was "you did not tell us it had to be student centered." To which the instructor replied, "Why would I have to tell you to make it student centered if you already “know” that student centered is the way you ought to teach?” After some discussion, the students agreed that they “learned” the definitions and that one strategy was more effective than the other, as pieces of information to be stored in memory. They did not, however, use that kind of “knowing” to make decisions about their actions. The lack of integration of thinking, feeling, and acting suggested they had not engaged in meaningful learning.

In another instance, a student wrote “There is no excuse for not giving girls the same opportunity as boys!” after reading an article on how girls and boys are treated differently in science classes. Two weeks later she reported on an exploration of the zoo, and stated (as noted earlier): “The next area was not any place the girls would want to go, nor would I take girls. It would just be of interest to some boys, because it was filled with snakes and other reptiles.”

Science as a Way of Knowing, a Way of Learning. Traditional students’ lack of connection between science as a way of knowing (and thinking) and science as a way of teaching and learning may be best characterized by this statement: “I don’t feel various points in science, like evaluation, should be viewed in a scientific way.”

A chapter in their textbook emphasized the need for using alternative assessments. Students agreed with the book that assessing student performance through a journal was a good form of assessment. In fact, they preferred it to paper and pencil tests. However, when asked to generate criteria to use for assessing their journals, statements like these were common: “Journals should not be graded. That I did it and I tried is all that matters.”

Making Work Public. When asked to describe how they were making sense of data in their journals, several traditional students said, “ Journals are personal things. I shouldn’t have to share my thinking in class or in a journal.“ They did not want to make their work public. Exit interviews suggested they were not willing to expose their thinking for fear of being "wrong." It was more important to look good than to learn.

Fear of Failure

Fear of failure and fear of ambiguity were prevalent among the preservice learners.

> I think I am so afraid of the children failing and myself failing as teacher, it was easier for me just to tell the answers to them (students in her internship class) than let them fall down and pick themselves back up on their own.

Another student said, "I'm scared to death to teach science. My teachers were not motivating. I'm scared that I'm going to do the same thing."

Nature of Science

Most students were explicit that their view of science prior to this course was strictly book learning they found boring and difficult. At the end of the course, some nontraditional students said the view of science as inquiry was something they liked and perceived they could do with children. One student said,

> I loved science when I was growing up, only I did not know it was science. My father always took me out to investigate nests, snakes, birds and other living things. It was great fun! I just never knew that was science.

Assessment and Evaluation as a Tool for Learning

The role of questions and skepticism was seen again in a different situation. It was difficult for traditional preservice teachers to see the difference between assessing and giving feedback to a product, or an idea, that a classmate presented from evaluating the person. They were uncomfortable with anything they perceived to resemble doing self assessment or peer assessment. Asking a peer for the evidence and the reasoning patterns that led to the idea a person was presenting was not a socially acceptable thing to do. One of the expected consequences of such action was that the person being questioned would then turn around and question the first person's ideas. There was a “quid pro quo” or “tit for tat” mentality. Instead of viewing such turnabout as a desirable event, a way for everyone to improve their work, which is a way science grows, traditional students placed negative value on it.

For example, students were given the opportunity to present a lesson plan to the class to obtain feedback from the group before turning in their final lesson plan to be graded by the instructor. After each presentation, the instructor asked the class the following question:

> If you had to teach this lesson tomorrow morning, what more would you want to know so you would feel totally prepared to teach it? Take five minutes and jot down your questions on a piece of paper. We will go around the room and give you each an opportunity to share your questions. Then you will give the written questions to the presenter who is free to incorporate answers to your questions in his or her final lesson plan. The presenter will not answer the questions now.

A common reaction to these directions from traditional preservice students was to resist asking the presenter any questions. When pushed, many asked a superficial question, often one that could be answered with a yes or no. Exit interviews at the end of the course with individual students revealed statements like this one: " if I ask her questions then she will ask me questions." Instead of viewing this as an opportunity to improve the product and learn from each other, many of the students sought a way to protect themselves from this interaction. In some instances students pointed out that if questions were asked that meant the student presenter had more work to do, and they really didn't want to do any more work. There appeared to be an underlying attitude that the assignment was just a hoop to jump through. “It has nothing to do with what I learn and I don't want to do any more work than is necessary.” This was tied to the close-ended notion that “I just have to do something to fulfill the requirement.” There seemed to be little or no curiosity about how to make something better, or to learn more. There was no sense of the expansiveness that characterizes science.

When the same questioning technique was used in classes where the majority of students had backgrounds in special education and, or, were second career learners, the students were enthusiastic about having the opportunity to generate questions for each other to improve their products. They interpreted the questions as non-threatening feedback to their work. They appreciated that the feedback was coming from their classmates. They realized that when the same question appeared several times from classmates, it must be something important to which they ought to attend. The instructor was perceived as just one more participant in the community asking questions, instead of being the authority asking questions alone.

A traditional student reflecting at the end of the semester in her journal noted of her peers

> …they are not comfortable with self assessing their progress which is most likely the result of a teacher directed, grade- focused past. It is sad to say that many students feel this kind of pressure and relate success with a ninety percent or better grade. Wouldn't it be nice if success was a feeling within and not a mark on a paper.

During a member checking episode in which the unwillingness to self assess was confirmed, a student said: "If we cannot even figure out how we are doing, how are we supposed to judge our kids? It's pretty scary."

Grades - a Driving Source of Resistance

That nothing less than an A grade was acceptable was explicit and the driving force for students' actions. Once the nature of science was explicated, students were confronted with the fact that the norms required in the culture of science conflicted with their expectations for what a class should be and the norms of the culture within which they functioned and found comfort. Thus they were confronted with the need to make a paradigm shift, a shift in worldview. They focused on the question, "How can I be guaranteed an A if the rules for being a learner have changed?" Their primary concern was the grade. They knew how to be successful at the game called "school", played in the traditional paradigm, and were resistant to having the rules changed. Their message was it's not fair to change the rules. For much of the semester, they expended energy resisting, rather than testing the new rules to see what would happen with them. Doing the work required to earn an A was not seen as a viable way to obtain it. Complaining about the nature of the workload was seen as a potentially effective strategy to lessen the load and earn an A. They put energy into attempting to socially manipulate the instructor by what students in a focus group, in each of two years, spontaneously described as the norm for their peers: "This cohort is always whining and complaining to get their way."

Some nontraditional students recognized the conflict between the culture of science and the culture of traditional preservice elementary teachers. Karen (fictitious name) wrote:

> Is it an inherent need for structure because the learner has a particular propensity for structure, or is it that this is the way I learned to be a successful student all my life and now the rules of the game have changed? I fear that I will not be successful under these new rules, and, or I do not have a complete picture of these new rules, or I have the picture but I do not fully understand how these new rules get implemented? The big issue is how will I be graded. Before, I understood that to get an A I needed to jump through specific hoops in an exacting way. Now I perceive ambiguity about what I am required to do to earn an A.

Karen exhibited a talent for inquiry. In her closing journal entry she acknowledged that she valued the new teaching paradigm because it:

> …relieved me of the pressure to only have one correct answer. … I like the idea that if I make a mistake in a fact, or an experiment with children does not work the way it is supposed to, I can have the children explore what to do next to see if they can make it work.

That this was an appropriate way to help children learn to solve problems, thus achieving an important goal in science, was liberating. That liberation felt good.

Control / Fear of Failure

Exercising control is a mechanism some people with high fear of failure use when confronted with ambiguous situations. Several traditional students where explicit that when they become teachers, they would demand absolute compliance from the children they teach. They intend to completely control their students by giving explicit detailed directions and parameters for both physical and intellectual events. Control was the primary criteria for any decision making. The teacher was the ultimate authority. They seemed to expect the instructor in the methods class to model that with them. Control was such a prominent issue that a student reported on an activity that went well in her classroom when she was interning and the university supervisor came to observe like this: "… (Students) got so excited that I started to get nervous because I didn't want my instructor to think I did not have control of the classroom."

Censure

As part of the ethics of science, scientists expect to censure a colleague whose actions are not appropriate to the conduct of science. In the student's culture, it was not acceptable to censure a group participant for inappropriate actions. They would not tell a classmate that his or her actions, or lack of action, needed to change, even when the person's actions were seriously interfering with the group's productivity. Students instead elected to complain to the instructor and expected the instructor to censure the student for inappropriate action.

Analytical Frameworks Comparing Student Culture to Culture of Science

Spector, Strong and LaPorta (1998) described the biological evolution of humans as a basis for science, pseudoscience, charismatic religions, and ideological dogma. That lens of biological evolution sets a foundation upon which to present analyses from the other theoretical frameworks used in this study: Humans inherited two opposing neurological/hormonal instincts. They are curiosity and safety seeking. The culture of science is an outgrowth of the human genetic characteristic called, "curiosity". Science is a culturally derived method for systematically and efficiently exercising curiosity. Pseudoscience, charismatic religions, and ideological dogma are an outgrowth of the human characteristic called, "safety seeking". These two basic opposing tendencies, curiosity and safety seeking, lead to two opposing emotional and mental life styles in humans.

These life styles are distributed along a continuum with recklessly exploring- curiosity- and excessive caution- safety seeking- at the extremes. Where one is genetically along this continuum determines the beginning point, but experience can modify it. The true range of possible modification of the genetically set point is limited, but what those limits are is an empirical question.

The curiosity-based life style is explorative, adventurous, and growth oriented, while the safety-seeking-based life style is constrictive. Science has developed as a highly efficient, effective, and satisfactory means of exercising curiosity which is capable of being taught and culturally transmitted. It is a synergistic, positive feedback system, which is expansive in nature. The questions and discovering methods to answer them are the primary reinforcing mechanisms, not the answers (Glickman & Schiff ,1967). Scientists don't look for end points and certainty, but rather new questions and pathways that further increase the activity. Thus a positive feedback system exists. Science seeks and encourages skepticism, questioning of established doctrines, and intellectual confrontation. Scientists are willing to expose their theories and findings to the heartless scrutiny of their colleagues. As science has become more complex, cooperation and collaboration have emerged as important features of the scientific enterprise.

The opposing tendencies of safety-seeking and harm-avoidance lead to an emotional approach to life that seeks certainty, assurance, and stasis. It is, therefore, a negative feedback system which is constrictive as opposed to expansive. The urge for safety seeking that evolved along with curiosity is essentially constrictive and inimical to the exercise of curiosity and questioning. It looks for unquestioning acceptance. These tendencies are characteristic of pseudoscience, charismatic religions, and ideological dogma. Practitioners do not seek new knowledge but merely confirmation of fixed, “eternal Truths”. Confrontation and skepticism within the group are discouraged. Conformity is the watchword. Often these movements center around a charismatic leader. Statements of certainty, not the probabilistic statements made by scientists, are typical. "Truth" is often revealed, not discovered .

The dominant culture of the traditional preservice elementary teachers studied appeared to be more consistent with safety seeking, than with curiosity driven science.

The cultural clash between science and the culture of traditional preservice elementary teachers is presented in table 1 from three perspectives: The first perspective emphasizes the ethical traditions of science as noted in the NSES (NRC, 1996). The second is from the perspective of the nature of science in science teaching showing how the two contrasting cultures are expressed in science teaching and learning in a course designed as a scientific inquiry. The third perspective is from social psychological theory relating to the need for achievement and fear of failure. The characteristics listed in both columns in the third perspective are derived from McClelland’s work (1985) and the earlier work of Murray (1938). The characteristics listed on the left for the culture of science are also characteristics compatible with paradigm shifters and paradigm pioneers in science education. The characteristics listed on the right are consistent with the culture of the traditional preservice elementary teachers. Together, these perspectives illustrate the cultural clash.

Table 1

The Clash of the Culture of Science and the Culture of Traditional Preservice Students

Perspective	Culture of Science	Culture of Traditional Preservice Elementary Methods Students
1. Ethical Traditions of Science	Desire knowledge.	Do not express desire for knowledge; Satisfied with extant knowledge.
	View science as a way of knowing and understanding.	View science as a fixed body of knowledge.
	Value peer review.	Don't value peer review-only review from instructor matters.
	Make work public.	Keep work private between student and instructor.
	Be open to criticism (of ideas and products).	Criticism (of ideas and products) is offensive and not permitted in a group or class.
	Truthful reporting of methods, procedures, and outcomes of investigations.	Expect to accommodate methods, procedure, and outcomes to arrive at the "right answer."
	Censure those who violate ethical traditions.	It is not permissible to censure a classmate. That is the responsibility of the instructor.
	Respect the rules of evidence.	Individual personal experience overrides evidence in a research base.
	Use empirical standards.	Use personal beliefs.
	Use logical arguments.	Use logical arguments.
	Skepticism.	Unquestionable acceptance.
	Strive for "best possible" explanation that is subject to change as new evidence becomes available.	Explanations should be "fixed". Stop seeking or ignore new evidence so as not to change explanations.

(Table Continued)

	Explanations must be consistent with data.	Explanations need to be consistent with prior beliefs.
	Explanations must make accurate predictions.	One prior personal instance is enough to accurately make predictions.
2. Teaching/ Learning		
Learners are rewarded for:	Identifying problems.	Stating answers.
	Divergent thinking.	Compliance and conforming to a "group think".
	Taking intellectual risks.	Staying intellectually safe. Not speaking unless sure I am right.
Learners expect to:	Ask questions.	Not ask questions.
	Test assertions (Seek cause and effect).	Accept authority's assertion.
	Have opportunity to investigate.	Be told the one correct answer by an authority.
	Determine for myself what to think and how.	Be told what to think and how.
	Collect data from multiple sources myself.	Use one source of data-the authority.
Learners assume:	Knowledge is dynamic (changes with new evidence).	Knowledge is static.
	My interpretation matters and so do those of other people in class.	Only the teacher's interpretation matters. My interpretation must match that of the teacher (Guess what is in the teacher's head).
	Multiple perspectives are valuable (necessary to construct my personal meaning).	There is only one way to think about something. One linear structure exists.

(Table Continued)

	Cooperate in answering questions and solving problems.	Answer questions and solve problems independently.
	An open mind.	New information will be consistent with prior beliefs. When it is not, it is dismissed.
	Need to be skeptical and analytical.	Need to accept without questioning.
	Classroom is full of chatter	Classroom appears orderly and quiet.
	Children will behave appropriately when given opportunity and freedom to engage in meaningful exploration.	Children must be controlled intellectually and physically by narrow detailed directives.
Learners are accountable by:	Inventing explanations and testing them.	Memorizing and following directions.
	Interacting with other people and ideas.	Working independently and protecting my ideas and products.
	Challenging ideas. Question other's ideas seeking evidence and logic used.	Being polite by "yes-ing" ideas (It's rude and unacceptable to confront other's ideas).
	Holding decisions in abeyance-tolerating ambiguity.	Jumping to conclusions. Bringing immediate closure.
	Negotiating among teachers and students to determine course actions.	The teacher alone determining course actions.
	Reflecting and engaging in metacognition.	Summarizing exactly what was given.
	Documenting processes and findings.	Repeating through recall what was received from the authority.
	Supporting an idea with evidence and logic.	Appealing to authority to support and idea.

(Table Continued)

Learners Perceive:	Science as an adventure and "do-able."	Science as boring and difficult.
3. Psychological Profiles	High need for achievement- Low fear of failure.	Low need for achievement- High fear of failure.
	Basic drive is to do tasks to achieve.	Basic drive is to be; to exist.
	Process for achieving is reinforcing.	Not doing any more than necessary to "get by" doing a task is reinforcing.
	Choose tasks of moderate difficulty. Like a challenge but want to succeed.	Choose very simple tasks with little challenge.
	Like competition. Do well in situations where they are competing against others of their ability.	Do not like competition.
:	Have a high tolerance for ambiguity. Like problem areas having many potential ramifications and solutions.	Do not tolerate ambiguity. Do not like problems having more than one solution.
	Have a strong tendency to remember unfinished tasks and return to them until they are finished.	Likely to forget unfinished tasks and focus on what they have finished.
	Like feedback. Want to know how they are doing.	Like feedback only when it is consistent with their ideas.
	Are independent and "inner" directed rather than "other" directed. This makes them non conforming and resistant to conforming pressures.	Are "other" directed and conforming. Readily acquiesce to conforming pressures.
	Set long-term goals and can postpone gratification.	Focus on short - term goals. Are discouraged when they need to postpone gratification.

A social action inventory by Lowry (1989) also supported the conflict in culture. A set of four color coded cards with statements on them for people to identify which set of statements was "most like me" was developed. Colors designated a set of statements that characterized individual's preferred mode of operating. It is common for a majority of teachers in schools to choose the gold card. Sample sentences from the gold card follow:

> I am practical and sensible, have a strong sense of right and wrong, and follow rules and respect authority. In school I like teachers who set routines and have organized ways of conducting classes. I prefer teachers who stay on one topic at a time. I like subjects that are useful and traditional. I like traditions. I know what I want and realize what I have to do to get it. I take pride in running a class and holding a position in school activities.

Teachers with a propensity for science and others interested in science commonly choose the green card:

> I am curious, investigating, and form my own ideas. I like to look at the big picture, enjoy activities that require problem-solving, set my own standards and seek fundamental truths. In school I like to focus on my ideas until my desire for understanding is satisfied. Many things interest me. I like to find ways to design and even invent something new in school.

These cards were given to the fifth class in this study. The self reports confirmed national data indicating "gold" dominated. A few people indicated the blue as well as the gold represented them. Pertinent statements from the blue card include:

> I like to get along with people and look after them. I fit well in situations. I think about the future, a perfect world, good friends, and love. I like my teachers, especially those who are friendly. My favorite subjects are about people, such as language, drama, literature, and psychology. I really like being well thought of and need frequent reassurance.

Conclusion

The learners with low need for achievement found the whole question of inquiry and being open-ended very ambiguous, because they did not know how it would turn out. They did not like it and resisted learning via inquiry. While all students' initial resistance to learning through inquiry was derived from a concern about grading, most nontraditional students were able to hold that concern in abeyance enough to pursue the inquiry at hand. Most traditional students had great difficulty doing that.

Low need for achievement coupled with high fear of failure is related to the safety seeking aspect in culture. An ambiguous situation promotes curiosity, an unambiguous situation does not. The person who finds curiosity exciting is going to like ambiguous situations, and will like doing open-ended inquiry. The inquiry will be perceived as freedom, stimulating, and exciting. A person with low need for achievement will want safety and certainty and not exhibit curiosity.

The contrasts presented between the culture of the traditional preservice elementary teacher and (a) the ethics of science presented in the NSES, (b) the nature of science as revealed in science teaching, (c) the biological evolution of curiosity as a basis for science, (d) social psychology relating to need for achievement and fear of failure, and (e) preferred style of social action are five different ways of describing the same culture. These multiple frames of analysis provided triangulation supporting the conclusion that there was a discrepancy between the culture of traditional preservice elementary teachers and the culture of science in the preservice methods classes studied.

Emergent Grounded Theory

The multitude of seemingly disparate events inhibiting students learning through open-ended inquiry made sense when the concept of culture was used as a conceptual organizer. The culture of the traditional preservice elementary teachers, grounded in the data, emerged. Comparing that emergent culture to the culture of science resulted in a grounded theory to explain the difficulty many traditional preservice students encountered in these elementary science methods classes and their resistance to inquiry teaching. The grounded theory is composed of the following propositions (Whetten, 1989): (a) The culture of traditional students who are commonly attracted to teaching in elementary schools is antithetical to the culture of science; (b) On an individual level, to the extent that a person attracted to teaching in an elementary school is steeped in a culture that reflects safety seeking, the person will be anxious and frustrated by learning through inquiry and to teach science as inquiry; (c) To the extent that a person attracted to teaching in an elementary school is steeped in a culture that reflects low need for achievement and high fear of failure, the person will resist learning through inquiry and teaching science as inquiry; and (d) To the extent that a student, whether traditional or nontraditional, is bound to the culture of the traditional preservice elementary teacher herein, the person will not be willing to test thinking, feeling, and acting consistent with the culture of science. This will inhibit the learner's success in a course designed as an open-ended inquiry.

Implications

Given that the NSES indicate decisions teachers make regarding the teaching of science are intended to reflect the culture of science, traditional preservice elementary teachers are being asked to function in a way that is antithetical to their culture. The decisions teachers need to make, and the subsequent actions required in order to learn and teach through inquiry, require a major shift in both explicit and implicit belief systems that comprise preservice teachers' worldviews.

The discrepancy created by the contrast in cultural underpinnings of science and of traditional preservice elementary teachers may pose an even bigger problem for preservice students and their instructors than the fact that they do not know much science content and were unsuccessful learners in science in their own schooling. Not only are we asking the preservice learners to teach a subject about which they have little content knowledge and with which they have had little experience, but we are asking them to think, feel, and act (learn) in a way that represents a culture antithetical to the culture they bring with them to the preservice class.

Science teacher educators need to deliberately design ways to help prospective teachers begin to alter their worldviews. We can provide opportunities for learners to induce understandings of the nature of science and the contrasting belief system. Specific tasks that foster high need for achievement could also become part of methods courses to help students develop attributes that enable people to teach science that is consistent with today's goals. Further, we need to accept that changing a person's worldview anchored in the culture in which one lives is a complex time consuming challenge that requires more than one methods course. We need to ensure the entire program of study for a preservice elementary teacher operates in the same paradigm. The National Science Education Standards' emphasis on inquiry, nature of science, and meaningful learning established a context that spotlights the culture of traditional preservice science teachers and creates a major challenge for science educators responsible for designing learning opportunities in science for preservice elementary teachers.

Questions for future research

Many questions emerged from this study that warrant further research. Some of them follow:

1. If we test classes of preservice teachers in science methods for elementary schools using explicit tasks from McClelland's work, will they support the theory emerging from this study relating to high and low need for achievement and fear of failure?
2. To what extent is the culture based on safety seeking described herein prevalent in preservice secondary teachers?

3. To what extent is the culture of traditional preservice elementary teachers visible among inservice elementary teachers? If it is still visible, but to a lesser extent, what process caused the change, e. g. was it a weeding out process?
4. What procedures are currently being tested that have potential to mitigate an individual's resistance to inquiry in a population with the culture described herein for traditional preservice elementary teachers?

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THE NATIONAL SCIENCE TEACHING STANDARDS AS THE BASIS FOR PORTFOLIO ASSESSMENT

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Preparation of teachers who are reflective about their practice continues to be a dominant theme in teacher education. As stated by Richert (1990, p. 525): "The ability to think about what one does and why - assessing past actions, current situations, and intended outcomes - is vital to intelligent practice, practice that is reflective rather than routine. As the time in the teaching process when teachers stop to think about their work and make sense of it, reflection influences how one grows as a professional by influencing how successfully one is able to learn from one's experiences." The need for teachers to be reflective practitioners has been well established since the National Commission on Excellence in Education (1983) recommended that teachers become active decision makers concerning all elements of teaching and learning. Teachers of today must not only know the subject matter but also have the ability to understand that subject matter from the perspective of the learner.

As a teacher educator, I have attempted to incorporate reflective thinking, teaching, and evaluation as major goals in my course work with pre-service elementary education teachers. For, it is when pre-service teachers are asked to analyze and reflect on lesson plans and instructional practices that they gain true insight into effective teaching. These reflective teaching experiences then lead to professional growth and development and improvement in the beginning teacher's ability to make appropriate decisions for themselves and the learner.

Likewise, teaching portfolios are receiving increasing attention as effective tools to promote reflection among both experienced and pre-service teachers. Proponents claim portfolios can provide an opportunity and a structure for teachers to document and describe their teaching; articulate their professional knowledge; and reflect on what, how, and why they teach. Developing a reflective portfolio encourages teachers to become more reflective about their own instructional practices. Based upon these premises, I implemented the use of portfolios in the elementary education science methods course over five years ago. I have been very pleased with its effectiveness in enhancing my students' skills in becoming a reflective teacher.

About two years ago, I became increasingly interested in the material presented in the National Science Education Standards, and consequently, committed to sharing the Standards' importance to the field of science education with my elementary education students. The challenge then became not whether to incorporate the Standards as part of my semester syllabus, but how. As in many teacher education programs, elementary education majors take only one three credit hour course in science methodology. I already do not have enough time in the semester to share with my students all I think they need to know to be successful teachers of science! How could I possibly add one more item to the syllabus? The already required portfolio became the most logical answer. Now that the portfolio is organized around the National Science Teaching Standards, my students not only have practice in reflection techniques, but they also are gaining an understanding of what the National Science Standards are and how the Standards can be implemented into daily lessons and teaching strategies in their future classrooms.

Sections of The Science Portfolio

The portfolio, as used in the science methods course, provides the elementary education students with a personal tool for reflecting upon their teaching skills, knowledge and understandings. The science portfolio is an edited collection of the evidence of professional growth and reflections representing progress toward attainment of competencies as stated in their personal goals, the National Science Teaching Standards, and the Oklahoma State University's core concept and goal of "integration". The portfolio also provides the basis for self-assessment and instructor evaluation of the pre-service teacher's progress towards those ends. The science portfolio is composed of the following major sections: personal goals, evidence of meeting the Standards, and evidence of demonstrating competency in the OSU Core Concept of Integration.

Personal Goals

To guide and individualize portfolio development, each student is required to list and describe a minimum of five personal, professional goals (Appendix A). These goals should guide the students by helping them focus their future professional plans and the steps required to achieve those plans. Students are asked to imagine and describe their ideal teaching position five years after graduation. Then they are to consider the following questions: What will you need to know to perform well in that position? What skills will you need to have? What attitudes and dispositions will you need to develop to succeed and be satisfied with your work? What experiences do you need to prepare you for this position?

In addition, throughout the portfolio, each student completes a "Brief Reflection Form" (Appendix B) for each piece of evidence, explaining how that item of evidence included in each section represents progress toward these personal goals.

Meeting the National Science Teaching Standards

"To teach science as portrayed by the Standards, teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching" (National Science

Education Standards, 1994, p. 28). To assure that competency and understanding of each of the six teaching standards have been met by the student, a minimum of three pieces of evidence must be included in the portfolio for each standard. These items of evidence and accompanying reflections in the portfolio must show how knowledge and skills in the following standards have been acquired:

- Teaching Standard A: Teachers of science plan an inquiry-based science program for their students.
- Teaching Standard B: Teachers of science guide and facilitate learning.
- Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning.
- Teaching Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.
- Teaching Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.
- Teaching Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program.

The 'Brief Reflection Form" that accompanies each item of evidence must explain how the student is making progress toward gaining competency in that standard in which it represents.

Oklahoma State University Professional Education Council Core Concept

OSU's professional education programs are devoted to the concept of integration. Professional education students learn to integrate personal experiences with fields of knowledge and with teaching based on sound theory and research driven by educational practice. Demonstration of competency in the OSU Core Concept will be done by students completing the "Reflective Commentary" (Appendix C), which is a short summary of the total portfolio experience.

Portfolio Requirements

A true portfolio must be student owned. The actual contents should reflect what each individual student knows, cares about, and is able to do in order to teach well. Pre-service teachers should be given explicit directions about the form and procedure of portfolio documentation, as well as guidelines about the types and amount of evidence to include and how the portfolio will be evaluated (Appendix D). However, they should also be given control over selecting the particular evidence to satisfy the purpose of the portfolio. Therefore, except for the following required items, the exact nature of the portfolio contents is determined by the individual student. Each portfolio must contain the following:

1. Three ring binder with divided sections
2. Title page and table of contents
3. List of minimum of five personal, professional goals
4. Minimum of three items of evidence for each national science teaching standard
5. One page "Brief Reflection Form" for each item of evidence
6. Reflective commentary

7. One professional journal article critique for each national science teaching standard.

Portfolio Assessment

In order to evaluate the pre-service teachers' levels of understanding and competency of the teaching standards, an assessment rubric was developed (Appendix E). For feedback purposes to students, scores for individual items and sections of the portfolio are given, followed by a holistic score for the entire portfolio.

Conclusions

I have found the use of portfolios in science teacher education to play a critical role in positively influencing pre-service teachers' beliefs and attitudes toward becoming reflective practitioners. Furthermore, when I incorporated the National Science Teaching Standards as the basis for the portfolios, I discovered that the portfolios also positively influence the elementary education students' own self-concepts about their ability to teach. Once the portfolios are completed, the students have gained an understanding of what the Standards mean, and have gathered personal evidence to demonstrate their competency in those Standards. They actually feel good about science and about their ability to teach science. Semester after semester I hear comments such as "I actually know more about science than I thought I did" and "I think I am ready and capable of teaching science now!" For an elementary science teacher educator, I must admit that that is my ultimate goal: for elementary education majors to overcome their phobias about science and the teaching of science. The portfolios intertwined with the National Science Teaching Standards are helping me accomplish that goal.

As stated in the National Science Education Standards (1994, p. 27), "Science teaching is a complex activity that lies at the heart of the vision of science education presented in the

Standards. The teaching standards provide criteria for making judgments about progress toward the vision; they describe what teachers of science at all grade levels should understand and be able to do." By making the Standards as the basis for the science portfolio development, my students are experiencing the integration of the complex nature of science education and personalizing it into their own philosophies of teaching. This would not be accomplished by having them just read about the Standards or me just lecturing to them about their benefits. The portfolio project does that for me, or rather, for them!

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Appendix D
National Science Teaching Standards and Suggestions for Contents

STANDARDS	SUGGESTED EVIDENCE
Teaching Standard A: Teachers of science plan an inquiry-based science program for their students. In doing this, teachers: • Develop a framework of yearlong and short-term goals for students. • Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students. • Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners. • Work together as colleagues within and across disciplines and grade levels	Unit/lesson plans Learning centers Interactive bulletin boards Samples of student work Field trip plans
Teaching Standard B: Teachers of science guide and facilitate learning. In doing this, teachers • Focus and support inquiries while interacting with students. • Orchestrate discourse among students about scientific ideas. • Challenge students to accept and share responsibility for their own learning. • Recognize and respond to student diversity and encourage all students to participate fully in science learning. • Encourage and model the skill of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.	Lesson plans with modifications Teaching styles Video of teaching Case studies Multicultural lesson plans Activity centers
Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers • Use multiple methods and systematically gather data about student understanding and ability. • Analyze assessment data to guide teaching.	Self-made tests Rubrics Philosophy of education Resume Transcripts Future plans/goals

- Guide students in self-assessment.
- Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makers, and the general public.

Alternative assessment ideas
Pre-assessment products
Tutoring assessment
IEP sample

Teaching Standard D:

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- Structure the time available so that students are able to engage in extended investigations.
- Create a setting for student work that is flexible and supportive of science inquiry.
- Ensure a safe working environment.
- Make the available science tools, materials, media, and technological resources accessible to students.
- Identify and use resources outside the school.
- Engage students in designing the learning environment.

Diagram of classroom
Parental involvement plan
Discipline plan
Substitute experience
Conferencing guidelines
Personal library resources
Classroom safety plan
Classroom science material list
Use of technology plan
List of community resources
Local field trips
Outdoor education lessons

Teaching Standard E:

Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers

- Display and demand respect for the diverse ideas, skills, and experiences of all students.
- Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
- Nurture collaboration among students.
- Structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse.
- Model and emphasize the skills, attitudes, and values of scientific inquiry.

Articles written
Grants/awards
Workshops/conferences attended
Computer literacy sample
Work experience
Group projects
Science fair projects
Research papers

Teaching Standard F:

Teachers of science actively participate in the ongoing planning and development of the school science program. In doing this, teachers

- Plan and develop the school science program.
- Participate in decisions concerning the allocation of time and other resources to the science program.
- Participate fully in planning and implementing professional growth and development strategies for themselves and their colleagues.

Community service
Professional organization memberships
College organizations/ leadership roles
Interviews of teachers and principals
Teacher in-service

USING WEB-BASED PORTFOLIOS TO SUPPORT ELEMENTARY SCIENCE TEACHER LEARNING

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Background & Purpose

In recent years, teaching portfolios have gained fairly wide acceptance in teacher education. They are broadly defined as a *collection of evidence* that demonstrates some aspect of teachers' knowledge, skills, or dispositions (Dana & Tippins, 1998). However, teaching portfolios have been described in the literature in a variety of ways, ranging from *scrapbooks* and *extended resumes* to more complex notions of *perpetual spaces* to examine and evaluate practice (Bird, 1990). Support for teaching portfolios appears to stem from their potential to be transformative -- to support the "effective development of problem-solving, decision-making and communication skills" (Dollase, 1996) and to facilitate meaningful reflective practice (Dana & Tippins, 1998; Ducharme & Ducharme, 1996; Krause, 1996; O'Donoghue & Brooker, 1996; Shulman, 1998).

Reflection is considered by Dewey (1933) to be the hallmark of intelligent action in that we learn more from reflection on our experiences than we do from the experience themselves. Moreover, research on teacher development suggests that opportunities to engage in meaningful reflection on practice can play an important role in learning to teach (Abell & Bryan, 1997; LaBoskey, 1994; Russell & Munby, 1992). Although teaching portfolios have been touted as a *scaffolding for reflective teacher learning* (Lyons, 1998), Dana & Tippins (1998) caution that the mere process of assembling a portfolio does not necessarily offer opportunities to engage prospective teachers in meaningful reflection. They propose a model for science teaching portfolios that is firmly grounded in the literature on reflective practice and constructivism -- one that describes portfolios as "spaces where prospective teachers represent their unique constructions of what it means to teach science in ways which permit them to analyze, discuss and evaluate their own teaching practices and professional growth" (p.722). As teachers engage in portfolio development of this kind, they are challenged to revisit their own understanding of learning and teaching science, consider the implications of their tacitly held beliefs on classroom practice, integrate and structure knowledge in new ways, and represent their understandings in ways that are personally meaningful (Freidus, 1998; Grant & Huebner, 1998).

The development of hypermedia portfolios has been recently identified as a potentially powerful tool for supporting prospective teachers in engaging in thoughtful reflection about their own learning to teach experiences, and as a means of constructing and organizing representations that more closely represents the dynamic and complex nature of teaching and learning (Wisnudel-Spitulnik, Zembal-Saul & Krajcik, 1998; Zembal-Saul, 1998; Zembal-Saul, Dana, Severs & Boardman, 1999). Hypermedia authoring, like the development of teaching portfolios, is grounded in constructivist learning theory (Brown & Chignell, 1993; Jonassen, 1995; Kumar & Sherwood, 1997; Nicaise & Barnes, 1996). In its most powerful form, hypermedia is characterized as a cognitive tool (Derry, 1990; Jonassen, 1995). Hence, the development of hypermedia by teachers is both an act of construction and a representation of understandings associated with science specific pedagogy.

It also may be helpful to think about hypermedia authoring in terms of design. Perkins (1986) suggests that any form of knowledge construction can be considered an "act of design." Solomon (1988) further explains that *knowledge as design* maintains that the manipulation of representations of concepts supports the learner in thinking about them. Hypermedia authoring provides many opportunities for learners to engage in design by supporting the development of multimedia representations and providing flexible options for organizing information. In particular, "linking capabilities provide a way of making associations concrete and perceptible that otherwise remain abstract and intangible" (Brown & Chignell, 1993).

For several semesters, we have incorporated web-based portfolios into an elementary science methods course at Penn State University for the primary purpose of supporting teacher learning and development. Combining the development of teaching portfolios and hypermedia authoring was an attempt to engage prospective elementary teachers in meaningful reflection on their personal theories in light of new learning and experience, and to enhance that process with technology. In particular, using a web-based or hypermedia forum for constructing and presenting teaching portfolios was intended to provide a way for preservice teachers to create and revise multidimensional and interconnected representations of learning and to support them in thinking more flexibly and nonlinearly about the relationships between teaching and learning, as well as their personal theories, field experiences, and coursework.

Shulman (1998) suggests that when one designs, organizes and creates a framework for a teaching portfolio, he or she is engaged in a theoretical activity. Given that one's theory of teaching will guide the selection/creation of reasonable portfolio entries, what is considered to be worth reflecting on and documenting is also considered a theoretical activity. Thus, the teaching portfolios themselves provide an external representation of some aspect of the developer's understanding. With the added technological features of hypermedia, this external representation has the potential to better illustrate the complex, dynamic, problem-solving process of teaching and learning to teach. Below, we describe the setting for the project and provide an overview of the implementation of web-based portfolios across several semesters.

Elementary Science Methods

The elementary science teaching and learning course at Penn State University is designed around several central areas of emphasis. First, prospective teachers are actively engaged in learning science throughout the course. A conceptual change approach drives instruction; concepts are selected based on the *National Science Education Standards* (NRC, 1996) K-4 and 6-8 content guidelines; and inexpensive materials that are available at Wal-Mart or the local grocery store are used. The purpose of this strategy is for prospective teachers to experience, as learners, a more conceptual and inquiry oriented approach to science teaching and learning -- one that is consistent with contemporary reform efforts in science education.

Reflection is another critical aspect of the course. Preservice teachers are supported in their attempts to engage in critical reflection in a number of areas, including their past and present experiences as science learners, their beliefs about the nature of science and scientific inquiry, their emerging *theories* regarding teaching science for understanding and the role of children's ideas/thinking, and their experiences *testing-out* these theories with elementary children in school settings.

The science teaching and learning course is one of three subject-specific methods courses and complementary field experience taken during what is known as the Discipline Inquiry (DI) Block. This block of courses and field experiences is typically taken during the semester prior to student teaching. Beginning in the fourth or fifth week of the semester, prospective teachers are in schools approximately two days every week.

Web-Based Portfolio Development: The Evolving Nature Of The Project

For a number of semesters, we have been engaging prospective elementary teachers in the development of web-based portfolios as part of the elementary science teaching and learning course described above. As might be expected, we have learned a great deal from the process and the project itself looks somewhat different each semester as we strive to achieve a balance between the task and the technology to best support teacher learning (see Table 1).

Table 1
Project Evolution

Semester	# Students	Authoring Tool	Task	Product
Spring 1998	30	HyperStudio	Structured	CD Rom
Summer 1998	16	Claris HomePage	Open	Web-Based
Fall 1998	60	Claris HomePage	Guided	Web-Based
Spring 1999	150	MS Word 98	Guided	Web-Based
Fall 1999	190	Tool of Choice	Scaffolded	Web-Based

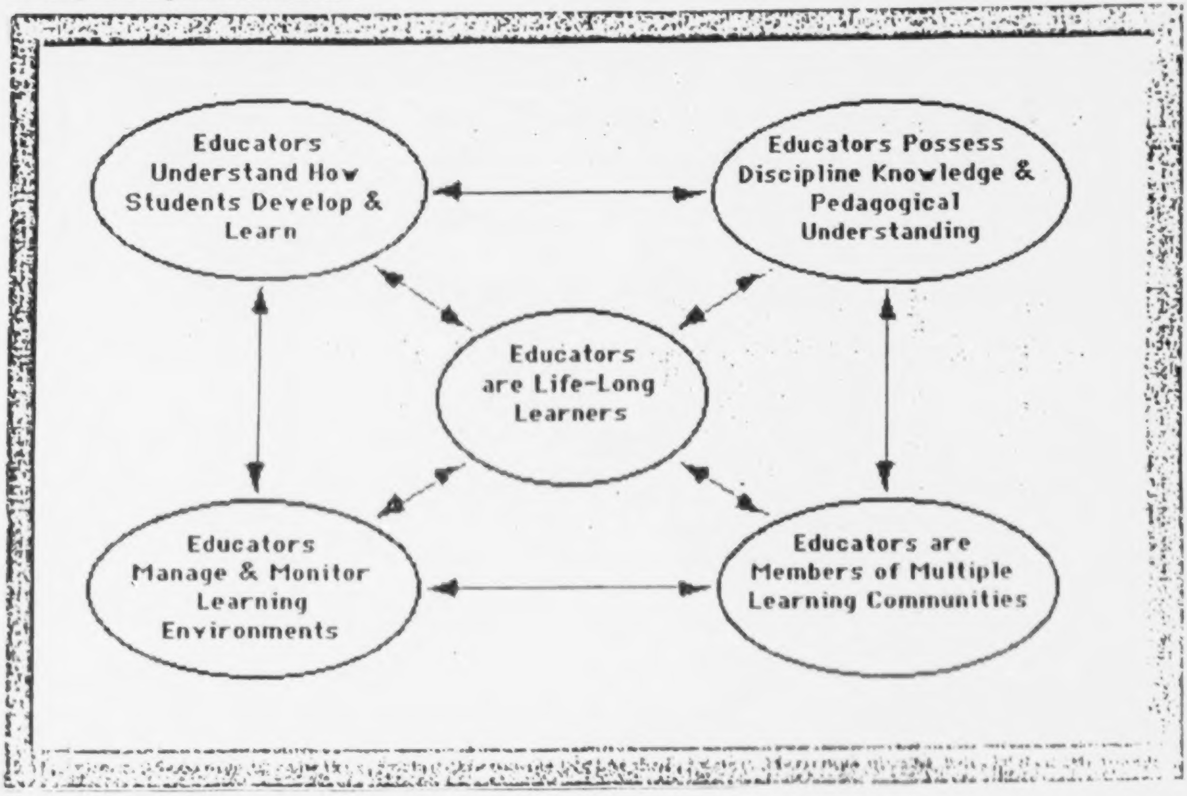
The earliest iterations of the electronic portfolio task were based on the work of the first author (see Wisnudel-Spitulnik, Zembal-Saul & Krajcik, 1998). Prospective teachers were provided with an electronic template to structure the selection of artifacts around planning, teaching and reflection. Analysis of these portfolios indicated that they had the potential to support thoughtful reflection (Zembal-Saul, 1998). However, we were interested in refining the process to assist prospective teachers in developing a framework for reflecting on key considerations for supporting children's science learning. Therefore, we piloted an extreme modification of the portfolio task with a small group of prospective teachers in the summer of 1998 (see Zembal-Saul, Dana, Severs & Boardman, 1999).

Unlike the previous semester, we moved from the private electronic format in which prospective teachers' portfolios were authored using HyperStudio™ and then burned to a CD-Rom, to a more public web-based product. Claris Homepage™ was selected as an authoring tool because of its "user friendly" interface and prominence in school settings. The task that prospective elementary teachers were presented with during this pilot was to demonstrate their understanding of supporting children's science learning. No structured guidelines were proposed. We then examined the nature of the portfolios holistically, as well as the artifacts, reproductions and productions used to support claims about science teaching and learning. Analysis of these web-based portfolios indicated that it was possible to differentiate among students based on the representations developed for their portfolios (Zembal-Saul, Dana, Severs & Boardman, 1999). Moreover, our findings supported the findings of other studies on teaching portfolios in that portfolio development can provide an effective vehicle for examining preservice teachers' emerging understanding of subject-specific pedagogy. Of particular interest were the unique features afforded to the portfolio developer through working in a hypermedia environment. Unfortunately, there was no strong evidence to support or refute the added benefits to prospective teachers when the portfolios are developed/authored in a hypermedia environment.

As a result of these efforts, we began to develop a task that encouraged prospective teachers to make better use of the hyperlinking and multimedia capabilities of hypermedia authoring. In particular, we were interested in the potential of the medium to support the development and integration of teacher knowledge through thoughtful reflection. Thus, in Fall 1998 and Spring 1999, the prospective elementary teachers were asked to organize their portfolios around the conceptual framework for the Elementary and Kindergarten Education (EKED) Program at Penn State (see Figure 1). Throughout the semester, they were supported in collecting and evaluating evidence (e.g., reading reflections, lesson plans, course projects) for the purpose of demonstrating their understanding, abilities and dispositions associated with various aspects of the framework. Analysis of these portfolios suggests that this approach indeed supported teachers in reflecting on relationships among university coursework, field experiences, and their developing personal theories about how children learn science and the role of teachers in supporting that learning.

Figure 1

EKED Conceptual Framework


Educators Understand How Students Develop & Learn
Educators Possess Discipline Knowledge & Pedagogical Understanding
Educators are Life-Long Learners
Educators Manage & Monitor Learning Environments
Educators are Members of Multiple Learning Communities

Throughout the evolution of this project, we came to see portfolio development as the construction of an integrated, coherent argument in which one justifies their assertions about teaching and learning science using multiple sources of evidence. Engaging in such an activity requires one to reflect in substantive ways on individual pieces of evidence, consider relationships among them, and compare them to personal theories about teaching and learning. The reality of the situation, however, was that we were finding it difficult to move our elementary education students

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beyond describing a collection of discrete pieces of evidence to using related pieces of evidence to demonstrate/justify understandings, abilities and dispositions associated with the program framework. This led to the current conceptualization of the web-based portfolio project.

In its most recent version the web-based portfolio project is organized around three main components: (a) a scrapbook, (b) program outcomes, and (c) a philosophy of science teaching and learning. Each component of the portfolio is designed to meet a particular need. For instance, the scrapbook, while superficial in nature, is portrayed as a place for prospective teachers to store their growing collection of evidence throughout the semester. Beginning during the first week of the course, prospective teachers are taught basic web development skills and are required to post course assignments to the scrapbook. The development of the scrapbook encourages prospective teachers to post their work in the course early and often, promoting ongoing technological skill development. In contrast, the program outcomes area of the portfolio is intended to encourage prospective teachers to reflect on the knowledge and abilities associated with teaching, and consider potential connections among the outcomes and their experiences in the course and concurrent field experience. This aspect of the portfolios is very similar in nature to the previous iteration of the project described above. Prospective teachers are introduced to this task several weeks into the course, after they have several pieces of evidence in their scrapbook. Finally, the development of a philosophy statement is designed to promote the construction of an evidence-based argument that reflects the prospective teachers' developing understanding of subject-specific pedagogy for supporting children's science learning. This assignment is introduced during the last few weeks of the course and requires education students to draw on a variety of sources to construct their arguments.

As one might expect, a great deal of assistance is required to help prospective elementary teachers engage in such an activity. Our students do not naturally think in terms of evidence, justification and claims. This type of discourse is modeled within the course, and time is specifically dedicated to portfolio discussions in which prospective teachers share and evaluate evidence in relation to claims about teaching and learning science. Not surprisingly, such an approach has served to establish goals for critical reflection and contributed to rich class discussions. As always, we are continuously engaged in research associated with portfolio development and seek to better understand the ways in which engaging in such a project impacts teacher learning.

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ASSESSING ELEMENTARY SCIENCE TEACHING IN A PERFORMANCE SETTING

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Innovative conceptions of assessment are currently being articulated that reflect reformed-based education practices. For example, McTighe and Ferrara (1994) state that the "primary purpose of classroom assessment is to inform teaching and improve learning, not to sort or select students or to justify a grade." (p. 4) The authors go on to specify that performance-based assessment refers to activities that directly assess students' understanding and proficiency. Student ability is revealed through responses, products, or demonstrations rather than simply recalling information (McTighe & Ferrara, 1994). Wiggins (1993) also notes that performance assessments should engage students in applying knowledge and skills that are used in the "real world."

Performance tasks in science education have continued to gain credibility as an appropriate strategy for assessing both students' abilities and conceptual understandings in science (e.g., National Science Education Standards, 1996; Hein &Price, 1994.) Lehman (1994) has also recommended performance tasks for assessing preservice teachers' ability to investigate science phenomena and use scientific equipment. Yet a common goal within an elementary science methods course is to help preservice teachers develop abilities related to teaching science as inquiry. A central question for teacher educators therefore becomes how to assess these abilities in alternative ways from traditional paper and pencil tasks.

In an effort to address this important issue, a special performance assessment was developed for 21 preservice teachers (hereafter called "teachers") enrolled in an elementary science methods course in the fall of 1998. The assessment focused on teachers' abilities to teach science through inquiry strategies rather than evaluating the teachers' science content knowledge. During the assessment, pairs of teachers were observed actually teaching a hands-on science lesson to a small group of students in an after-school program at a local elementary school. Following the teaching, time was set aside for the teachers to reflect on the experience with the course instructor and receive feedback on their teaching.

During the performance assessment, the teachers demonstrated their ability to teach science in ways consistent with the National Science Education Standards (National Research Council, 1996). Although numerous teaching standards could be assessed in a performance setting, this assessment focused on Teaching Standard B: "Teachers of science guide and facilitate learning" (p. 32). This particular standard was selected for the assessment because it reflected an ongoing theme within the elementary science methods and also modeled an alternative way for the preservice teachers to assess their own future students' understandings during science instruction.

Conceptual Framework

The conception and development of the performance assessment was guided by the work of Grant Wiggins. Wiggins (1998) states that the most meaningful assessments are what he terms "educative", such as those that involve authentic tasks and the assessments provide feedback that can be used to revise performance. According to Wiggins, an assessment task is authentic to the extent that the task:

1. Is realistic.
2. Requires judgement and innovation.

3. Asks the person to "do" the subject.

4. Replicates or simulates the contexts in which adults are "tested" in theworkplace, in civic life, and in personal life.

5. Assesses the person's ability to efficiently and effectively use a repertoire of knowledge and skill to negotiate a complex task.

6. Allows appropriate opportunities to rehearse, practice, consult resources, and get feedback on and refine performances and products. (pp. 22, 24)

Wiggins also characterizes the best assessment feedback as highly descriptive and matched to specific goals. In this case, the course instructor provided detailed feedback to each teacher accoring to the categories in the assessment rubric (see Table 1).

Assessment Preparation

Several weeks prior to the performance assessment, the teachers were given an orientation in class that included several handouts to help them prepare for the experience. One form was the scoring rubric itself, which identified the three areas to be assessed: how well the teachers invited inquiry; how well the teachers sustained inquiry; and how well the teachers attempted to assess inquiry (seeTable 1). A range of performance standards was presented in the rubric that illustrated high and low achievement in each of the three performance areas. A final rubric section addressing joys and concerns related to inquiry teaching completed the scoring total. An assessment outline was also presented (Table 2) as an aid to help the teachers plan how they would implement the teaching standards described in the rubric. Written responses on the outline were completed ahead of time by the teachers and brought to the performance assessment.

Table 1

Inquiry Science Teaching Performance Rubric

	High (3 pts)	Moderate (2 pts)	Low (1pt)
Inviting Inquiry	Upbeat interest-enthusiasm in topic	Some interest-enthusiasm in topic	Little interest-enthusiasm in topic
	Choice in materials encouraged	Some choice in materials	Few choices in materials
Sustaining Inquiry	Variety of questions including Open-ended and Reasoning: Why? What do you think?	Mostly factual recall questions: (What is . . ? How many . . ?	Few questions Mostly factual recall
	Flexible in direction of lesson; allowing students to shape lesson; welcome student input	Some flexibility evident	No flexibility
		Some student input accepted	Plan followed directly
Assessing Learning	Two ways to assess described on outline; one way attempted with students	Two ways to assess described on outline	One way to assess noted on outline
Journey as A Teacher (1 pt total)	Discusses important joys, dilemmas, concerns listed on outline		

Table 2

Science Inquiry Performance Assessment Outline

Category	Description
Inviting inquiry	How will you arouse the students' curiosity in the topic? How will you invite them to explore? Think about the questions you will pose; choices given to the students; your own personal interest in the topic; and the amount of freedom you will give the students.
Sustaining Inquiry	How will you encourage continued inquiry? What prompting will encourage active learning? Think about your flexibility in how the lesson develops; continued student input and choice; and time to investigate.
Assessing Learning	What are the students learning to do and understand in this experience? Think about ways to gain some insights into these abilities and understandings. Write out at least two meaningful assessment strategies. (Participation, oral/written explanations, diagrams, demonstration of concepts).
Your Journey as a Teacher	Note any joys, dilemmas, concerns, and issues that are important to you as become a "facilitator" of children's thought in science.

The teachers were also informed that they would be observed in pairs during the assessment with each one teaching a physical science topic to a small group of students. They could choose between two familiar topics, which had been previously explored in the methods course: sinking and floating or magnets. Additionally, the teachers were given background information and some suggested activities for their selected topic much like the preparation process required of any practicing teacher. The intent was to help the teachers better prepare a flexible plan in advance rather than to expect them to invent inquiry experiences on the spot.

The performance assessment took place in an elementary school with K- 5 children who were enrolled in an after-school program. A corner of the school library created an ideal setting for the assessment: accessible but removed from the disruption of the after-school activities. Several weeks prior to the assessment sessions, a schedule of assessment dates and times was given to the after-school coordinator who was responsible for selecting groups of four school students for each time slot. A schedule of time slots was then posted for the teachers to select a date and time for their session. Each time slot was for 45 minutes: 20 minutes for teaching, 20 minutes for reflection, and five minutes for clean up.

Assessment Event

At the scheduled time, two teachers came to the assessment area in the school and began arranging the hands-on materials for the activity. The teachers worked at adjoining tables allowing them to share materials if needed. On average, two elementary students explored the topic with each teacher. The two teachers were simultaneously observed teaching for twenty minutes using a feedback sheet as a guide for writing comments and giving scores. The teachers were clearly aware that they needed to create and sustain an active learning environment for the students. The scoring rubric served as a guide for accomplishing this goal by focusing the teachers' attention to questioning techniques, flexible teaching style, and ongoing assessment strategies. Consequently, each teaching session was extremely animated: the young students excitedly explored the topic while the teachers assumed the role of "facilitator" to the children's learning.

After the exploration with the teachers, the elementary students returned to their after-school activity area, while the teachers cleaned up the area and joined the course instructor for discussion, reflection, and feedback on their teaching. The assessment outline, which had been completed by the teachers ahead of time, was used as an informal guide to focus discussion of different aspects of the inquiry teaching and ended with a sharing of each teacher's perspective on their own journey as a teacher.

Findings

Planning

The teachers used the assessment outline (Table 2) to articulate their thoughts about inviting, sustaining, and assessing science inquiry prior to the actual teaching event. The prompts on the outline were written to help focus the teachers' thoughts on specific teaching strategies tightly linked with promoting inquiry. The prompts were also consistent with the science pedagogical themes modeled throughout the course by the instructor. The primary goal was helping the teachers "plan to be flexible" rather than requiring a detailed procedural lesson plan format that could possibly inhibit exploration on the students' part.

In general, the teachers written intentions were steeped in notions of being a guide to the students' investigations. For example, one teacher wrote,

> I will arouse the students' curiosity by having them guess and predict which objects sink or float. I will invite them to explore by letting them have choice in what objects they want to experiment with. I will pose such questions as, "Why does the object float?" And "How can you make it so the object (clay) will float?"

Other intentions focused on using thinking strategies such and prediction and inferring as ways to encourage active learning during the teaching.

Teaching

All of the teachers attained a score of "10" on the assessment reflecting the preparedness and effort of the teachers. They knew what was expected and had written out their detailed intentions ahead of time on the assessment outline. They were ready for the task, believed in its value, and were ultimately successful. A carbon copy of the feedback sheet with comments and scores was given to the teachers immediately at the end of the session.

Dialogue and Feedback

A lively discussion ensued consisting of teacher comments about how the students responded to the topic and reflections on their role in the inquiry process. The teachers' language was vibrantly mixed with comments about unexpected happenings, joys, or concerns they felt toward the experience.

Insights offered by the teachers were later clustered into the following categories:

1. Learning context: management issues and selection of materials.

2. Learner characteristics: different interests; different learning approaches; and different learner thinking patterns.

3. Self-awareness about teaching: types of questions to ask; when to talk or not talk; their own teaching style preference; and the struggles experienced in the role of facilitator to student learning.

The variety and richness of the insights shared by the teachers underscored the value of the experience. Within a brief period of time, multiple issues were encountered first hand followed by an immediate opportunity for the teachers to reflect and receive feedback on the experience.

Every attempt was made by the instructor to provide specific feedback (after Wiggins, 1998) to the teachers based on ideas raised in the discussion or observation notes recorded during each session. The observations were grouped according to the categories on the assessment rubric (inviting inquiry, sustaining inquiry, and assessment). A conscious attempt was made to be forthright with each teacher about any concerns, but these concerns were offered in an encouraging and affirming way. The journey metaphor (from the assessment outline) was also a productive way for the instructor to build dialogue with the teachers and acknowledge challenges faced by all teachers of inquiry-based science instruction.

The feedback tended to fall into the following categories:

Verifying: Acknowledging and recognizing those actions that were appropriate for the session. "Your upbeat approach encouraged the students to keep investigating the topic." "I liked how you provided many options for the students to choose from in their investigation."

Affirming: Supporting the thoughts and actions of the teacher. "You raise a good point because we all have this plan of what the students will do, but you were sensitive and watching them and being flexible."

Probing: Offering and exchanging ideas to ponder.

T(eacher): How do I explain this fact about magnets without using terms that are difficult for the students to completely understand?

I(nstructor): Well, do you have to explain it?

T: I think so because they are asking a question and I want to answer it. Or I'll ask, "Why do you think that happens?" And maybe they don't know or they'll say something that's not true. They're sort of guessing – and I can't accept that as, okay, I have to say something like "Well, actually this is why."

I: Let's talk about that for a moment. Maybe there is a level of explanation – so that when I said you don't have to explain – what I'm thinking of is, you don't have to take it to the level you thought you needed to.

Expressing Concern: Sharing forthright concerns in a sensitive way. "You seem eager to want to explain the science concepts. I'm glad you are able to explain the ideas so my feedback is simply, just keep holding back a little bit . . . Try to get a little bit more from the students . . . We all have this tendency because we think it's time now to tell them . . . that part of getting them to explain this way or that way is complicated. I'm just pointing this out, not as a fault."

Sharing Dilemmas: Confirming the challenges faced by teachers of science through inquiry.

T: The only thing I was concerned about, I mean you've got to let them find out for themselves, but at the same time you'd like them to feel accomplishment that they actually got it to float, so you have to kind of guide them, give them some direction. It was hard for me to just sit back. I felt I had to say something but at the same time, I didn't want to say too much . . .

I: But you're aware of that at this early stage in your career and I appreciate that. You want the students to explore but you also want them to have some success. It's a challenge I felt as a teacher.

(Another two teachers)

I: How are you going to have time to teach science this way?

T1: I definitely agree that I would much rather take a full hour to really know that they are grasping the whole concept . . . We rush children and if we rush them they just want to get done just to be done. They don't want to explore.

T2: They just want to get it done and not understand what they're doing.

I: I want to encourage you to hold onto that idea. Time is hard and it becomes an adversary for me at times. But you've got the National Science Education Standards, you've got the children on your side . . .

Teacher Evaluation of the Assessment

Immediately after the performance assessment, the preservice teachers completed an anonymous survey asking for their thoughts and recommendations on the experience. The overwhelming majority of preservice teachers believed the performance assessment experience was a valuable because it was consistent with their professional goals. Supportive comments included: increased confidence in hands-on teaching, heightened awareness of own teaching strengths and weaknesses, better grasp of assessment, and new opportunities to be flexible as a teacher. Recommendations for future assessments included letting the teachers bring in their own activities and expanding the time for the sessions.

Conclusions

An attempt was made to implement an alternative assessment format for preservice elementary teachers that focused on inquiry strategies when teaching science. In contrast with other assessment formats that were either hypothetical or reflective experiences (Guy & Wilcox, 1997) this assessment fostered numerous insights about teaching and learning for the teachers. As a result, the teachers perceived that assessment task to be educative: it was authentic and involved relevant feedback. As two students noted: “This experience has brought me one step closer to feeling more confident in my skills as a teacher.” The assessment was “a wonderful experience. This gave me insight into myself as a teacher and the areas of strengths and weaknesses I need to work on.” A common thought expressed was that the assessment was valuable: a rich teaching experience with young learners followed by helpful feedback.

Lastly, the sizeable amount of time required to administer the performance assessment is an issue facing teacher educators wanting to implement such an experience with their teachers. In this case over nine contact hours over three days was devoted to the event. In the end, the value of the experience as expressed by the teachers outweighed the time commitment involved.

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IMPROVING PRESERVICE ELEMENTARY TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENCE USING A CONCEPTUAL CHANGE TEACHING APPROACH

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The *National Science Education Standards* (1997) and *Benchmarks for Science Literacy* (1993) recommend that teachers prepare students to not only acquire a body of scientific knowledge and conduct scientific inquiries, but to understand the nature of science itself. Previous studies, however, have shown that teachers' views of the Nature of Science are not consistent with current definitions of the nature of science. Various approaches have been tried with differing levels of success in changing conceptions (Aguirere, Haggerty, & Linder, 1990; Bloom, 1989; Brickhouse, 1989, 1990; Brickhouse & Bodner, 1992; Briscoe, 1991; Gallagher, 1991; King, 1991; Koulaidis & Ogborn, 1989). A recent study (Dickinson, Abd-El-Khalick, & Lederman, 1999) provided evidence in support of using an explicit, reflective-based approach in helping teachers developing more accurate conceptions of the nature of science. However, the approach was not sufficient in changing all conceptions with most students, leading to a call to use a conceptual change approach to help teachers develop more adequate views.

The Nature of Science

Typically, NOS has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. These characterizations, nevertheless, remain fairly general, and philosophers of science, historians of science, and science educators are quick to disagree on a specific definition for the NOS. It is our view, however, there is an acceptable level of generality regarding the NOS that is accessible to K-12 students and also relevant to their daily lives. Moreover, at this level of generality virtually disagreement exists among historians, philosophers, and science educators (Lederman & Abd-El-Khalick, 1998).

In our view, the aspects of the scientific enterprise that fall under this level of generality and that are emphasized in the present study, are that scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional important aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws.

Conceptual Change Theory

Posner, Strike, Hewson, and Gertzog (1982) theorized that students remain committed to their ideas unless they are shown the necessity of modification. The student must be dissatisfied with the existing conception, meaning the student's idea must no longer make sense to the student in explaining the concept. A new idea must be intelligible as well as plausible. Finally, the new conception must be fruitful and make sense in many situations. Strike and Posner (1992) reiterated that their theory of conceptual change is not a prescription for instruction, but only conditions necessary for ideas to change. Conditions common to conceptual change teaching strategies (ie. Butts, Hoffman, & Anderson, 1993; Flick, 1996; Happs & Scherpenzeel, 1987; Joshua & Dupin, 1987) include: (a) identifying students' initial conceptions of a concept, (b) helping students recognize their ideas are not sufficient explanations for the concept, (c) presenting, or helping students to understand a conception that is an accurate idea, and (d) checking to verify an improvement of understanding of the concept.

Method

Context of the Study: An Elementary Science Methods Course

The first author taught the elementary science methods course (3 credit hours) in which participants were enrolled. Classes were held weekly in three-hour blocks throughout the semester. The course aimed to help preservice elementary teachers develop (a) a theoretical framework for teaching science at the elementary level, (b) a repertoire of methods for teaching science, (c) favorable attitudes toward science and science teaching, and (d) deeper understandings of some science content area.

Preservice teachers were assigned weekly readings that were mostly pedagogical in nature. They were also engaged in weekly hands-on/minds-on activities. These in-class activities were content-based explorations designed to help preservice teachers experience a variety of teaching methods and reinforce their understandings of key science concepts. The course assignments included an in-depth study of a science content area emphasized in *Benchmarks for Science Literacy* (AAAS, 1993) and chosen by preservice teachers. Each participant then interviewed an elementary student to elicit his/her ideas about the target science content area and presented the interview findings to the rest of the class. Each preservice teacher also submitted a paper illustrating the understandings that he or she had acquired as a result of studying the target content area, and contrasting those understandings with corresponding ideas elucidated by the interviewed elementary student. Next, preservice teachers wrote a series of three lesson plans specifically designed to address the interviewee alternative ideas or misconceptions. The lesson plans were to be designed with a conceptual change pedagogy (Posner, Srike, Hewson, & Gertzog, 1982) in mind. Additionally, preservice teachers wrote weekly reflection papers on the assigned readings and tasks.

This study aimed to explore the "effectiveness" of a conceptual change strategy on preservice elementary teachers' conceptions of the nature of science. The conceptual change strategy was used in addition to a direct explicit approach that included reflective components, which were shown to be effective with some elements of the nature of science in an earlier study (Dickinson, et al., 1999).

The specific question that guided this research was what is the influence, if any, of using a conceptual change strategy with a reflective explicit approach on preservice elementary teachers' views of the NOS?

Participants

The present study comprised one full semester of a preservice elementary science methods course. The cohort was made up of 28 undergraduate students enrolled in an elementary science methods course during the fall term in a mid-sized western state university. Participants were mostly female. Their ages ranged between 23 and 44 with a median of 28 years. These undergraduate students were seeking a BA degree in elementary education. Both cohorts were in the first years of their programs. None of the students had a strong science background, taking the minimum number of science credits (12) required for their B.A..

Procedure

The present investigation was qualitative in nature. Data collection spanned the full semester during which the study was conducted. Several data sources were used to answer the questions of interest. An open-ended questionnaire (Abd-El-Khalick, et al., 1998; Bell, Lederman & Abd-El-Khalick, 1998) was used to assess participants' views of the NOS prior to and at the conclusion of the course. The questionnaire consisted of seven open-ended items that assessed participants' views of the tentative, empirical, creative, and subjective nature of science; the role of social and cultural contexts in science; observation versus inference; and the functions and relationships of theories and laws. Semi-structured interviews conducted with 10 randomly selected students enrolled in the courses were used to establish the validity of participants' responses to the questionnaire. During these interviews participants were provided with their pre-instruction questionnaire and asked to explain and elaborate on their responses. Additional data sources included student reaction papers, and a researcher log that included reflections of each class session. Following instruction a final interview was conducted of 10 purposefully selected students. The researcher selected the students from reviewing student reaction papers and course discussions to note which students seemed to have good understandings, average understandings, or poor understandings of NOS to try to discern reasons for the discrepancy in understanding.

Students were given the questionnaires and interviewed prior to formal discussion of NOS in the course. Thus, formal discussions and instruction in NOS did not begin until the third week of classes. These questionnaires and interviews were analyzed to form an impression of the general conceptions held by students in the course. Overheads were made of the categories of conceptions and shared with the class as a whole to make them aware of their conceptions, a component of conceptual change. Students were given readings designed to make them aware of their own misconceptions of elements of the NOS (ie. Chalmers, 1982; Lederman, Farber, Abd-El-Khalick & Bell, R. L 1998; McComas, 1996; Popper, 1988; & Rudner, 1988) (See the reading list in the Appendix) and activities specifically designed to confront faulty understandings of elements of the NOS (Lederman, & Abd-El-Khalick, 1998; Abd-El-Khalick, 1999). NOS became a theme of the course, with the instructor making numerous references to the discussed aspects of the NOS throughout the course while students were engaged in activities, or while they were discussing ideas. Whether students were engaged in learning science content or pedagogy, they were often asked to reflect on how that content or those teaching strategies relate to NOS. The instructor kept a detailed log of all such references, prompts, and reflective opportunities. In addition to these verbal discussions, students were assigned to write seven papers in reaction to specific readings and videotape presentations related to the NOS. Before turning to discuss data analysis, a brief descriptions of the activities used is presented.

The Activities

Eleven different NOS activities were used in the present investigation. Detailed descriptions of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998; Abd-El-Khalick, 1999).

In general, these activities were generic in nature. Some of these generic activities were of the "black-box" variety. In such activities, students were shown a particular phenomenon and asked to infer how it works. Students were then asked to design and construct models that mimic the behavior of the original phenomenon without ever "seeing" what was inside the "black-box." Ensuing discussions focused on the distinction between observations and inferences, the role of models and theoretical constructs in science, the tentative nature of scientific knowledge, and the role of creativity in devising scientific explanations.

Intervention

During the first six hours in the course, the instructor engaged participants in 10 different activities that explicitly addressed the seven target aspects of NOS. Detailed descriptions of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998). Two of the activities addressed the function of, and relationship between scientific theories and laws. Two other activities ("Tricky tracks" and "The hole picture") addressed differences between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Four other activities ("The aging president," "That's part of life!" "Young? Old?" and "Rabbit? Duck?") targeted the theory-ladenness and the social and cultural embeddedness of science. Finally, two black-box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the above NOS aspects. The activities were purposefully selected to be generic in nature (not content-specific) given the participants' limited science content backgrounds. Each activity was followed by a whole-class discussion that aimed to explicitly highlight the target aspects of NOS and involve students in active discourse concerning the presented ideas.

This initial activity-based explicit NOS instruction was intended to provide participants with a NOS framework by introducing and, in a sense, sensitizing them to the target NOS aspects. These aspects became a theme that permeated the remaining course activities. Throughout the remainder of the course, participants were provided with structured and unstructured opportunities to *reflect*, both orally and in writing, on various aspects of NOS as they arose during course activities or as they related to course readings. Whether students were engaged in learning science content or pedagogy, they were often asked to think about how that content or those teaching strategies were related to NOS. This reflective component of the intervention aimed to help participants articulate and elaborate their acquired NOS understandings, and apply those understandings in various contexts. The instructor kept a detailed log of all these reflective opportunities, examples of which are provided in the following two sections.

Classroom discussions. Participants were often asked to relate the NOS aspects discussed at the outset of the intervention to other course science-content and pedagogy topics. For example, to contextualize earlier discussions of scientific theories, the instructor asked participants to examine and comment on the *Benchmarks* definition of evolution as a scientific theory (AAAS, 1993, p. 122). The ensuing discussion focused on the explanatory function of evolutionary theory and its role in generating and guiding several fruitful biological research programs. In the context of discussing assessment and evaluation practices and techniques, participants were asked whether and how NOS was related to the assessment of elementary students' science content knowledge. The ensuing discussion in the graduate section of the course highlighted the distinction between observation and inference as evident in the following excerpt:

> Student 1: Assessment is only a picture of what students might know, not . . . what they actually do know. It is like science. You are looking at pieces of evidence, trying to draw conclusions and then infer what the evidence means about what the students know about a given concept.
>
> Instructor: That is an interesting idea. It does relate to our discussions on NOS. Could anyone add to this discussion?
>
> Student 2: Yeah. It is like the "tubes" activity [one of the activities presented in the first two weeks of class]. With a lot of variety of assessments you can get a better picture of what the student knows than

> with only one method of assessment. With the "tubes" activity, if you pull only one string you will have less of an idea of what is inside the tube than if you pull all of the strings and see what happens.

In the undergraduate section of the course, the issue of "The Scientific Method" was brought up in the context of discussing a course reading related to assessing science process skills. The instructor raised the following questions, "Do you think there is a 'Scientific Method' that includes all of those process skills in a particular order? Can we use this 'Scientific Method' to assess students' mastery of process skills?" These questions started students thinking about the distinction between the finished products of science as they appear in professional journals and the actual work that scientists engage in during their daily activities:

> Student 1: That is how all the journal articles are written. Yes, there is definitely a scientific method.
>
> Instructor: Do you mean that this "method" is an actual step-by-step procedure just as is described in scientific publications? When you "do science" do you always ask a question, then observe, then hypothesize, then design an experiment, then collect data, then draw your conclusions in that order?
>
> Student 1: No, not really. It is more mixed up in order when you do it. When you write it up you kind of have to "figure out" a logical way to present what you did and then you can probably get to publish it.
>
> Student 2: Probably you do observations and all those things, but they are in different orders. Then when you write it up is when you put it in the order the magazine [journal] wants.

In the context of discussing unifying themes from the *Benchmarks*, the notion of "Models" was brought up (AAAS, 1993, pp. 267-270). The instructor asked the undergraduates whether this discussion was related in any way to earlier NOS discussions. Students referred to the "Tubes activity" in the attempt to explain the nature of "Models" and their importance in science:

> Student 1: It is like the tube activity.
>
> Instructor: How so?
>
> Student 1: You are seeing the evidence when you pulled on the strings of the tube and the evidence showed you how you could build your tube to match the real thing. You don't really know what the real thing

> is, but can approximate it through the model. If the model works like the real thing, it is a good model . . . the model can help explain what you are studying.

Children's literature books were often shared with participants and the question "What does this book have to do with science?" was almost always used to prompt discussions about NOS. For instance, at about the midpoint of each course section, *Earthmobiles as Explained by Professor Xargle* (Willis, 1991) was read to the class. This book discusses transportation on Earth from the viewpoint of aliens. The instructor asked, "Why would I read this book to you? What does this book have to do with science?" The ensuing discussion with students focused on the empirical and theory-laden NOS. Graduate participants noted that the nature of one's prior knowledge or perspective that is brought to bear on evidence does influence the conclusions or interpretations that one ends up with. Nonetheless, such conclusions or interpretations need to be consistent with one's observations:

> Student 1: It talks about different viewpoints.
>
> Student 2: Yes, it is like drawing conclusions based on your own viewpoint.
>
> Student 3: It is good for sharing how things can be described and interpreted from different viewpoints.
>
> Instructor: To me it is like science because the aliens are taking the evidence of what they observe and interpreting through their own lens. They are drawing conclusions and presenting them based on their prior knowledge and their interpretations from that evidence and knowledge. They don't know for certain if their ideas/interpretations are correct, but they are reasonably sure that their conclusions, based on their observations, make sense.
>
> Student 4: This is another nature of science thing again.

The above discussions might help to illustrate the importance of explicit prompts to get students to think about, and reflect on different issues related to NOS. Without such prompts, these discussions, which got students involved in discourse about NOS, were not likely to have taken place. Students' involvement in such discussions, we believe, is crucial for providing them with opportunities to clarify their ideas about NOS for themselves in the first place, and for others in the second place. It is noteworthy that toward the beginning of the course, these discussions were almost exclusively dependent on explicit prompts from the instructor. However, as the term progressed, students began to recognize on their own elements of NOS that were embedded in various course activities or readings. On several occasions, students themselves initiated whole-class discussions by posing questions. At this stage, the instructor's role shifted from prompting discussion about NOS to facilitating the discussion, providing focus, and helping participants to come to some sort of closure.

Written reflections. In addition to verbal discussions, participants were required to respond in writing to two reflective prompts related to NOS. For the first reflection paper, participants were asked to read the prologue for Penrose's (1994) *Shadows of the Mind: A Search for the Missing Science of Consciousness*, and answer the following questions: "Do the ideas in this reading fit our discussions of NOS? If yes, how? If no, why? In your discussion try to focus on the elements of tentativeness, creativity, observation versus inference, subjectivity, relationships of theory and law, and social and cultural embeddedness of science." This short reading is a dialogue between young Jessica and her father. The father, a scientist, goes into a cave to collect some plant specimens and Jessica goes along. While inside, Jessica wonders what would happen if she, her father, and others got trapped inside the cave. Eventually, Jessica comes to ask, "How could I know what the real world outside was like? Could I know that there are trees in it, and birds, and rabbits and other things?" (Penrose, 1994, p. 2). The ensuing conversation focuses on how we "know" and how "valid" our knowledge is, as Jessica's father tries to explain to her how much they could learn about the outside world just by observing whatever shadows that might form on their cave walls. Participants' responses to this prompt focused on the social, theory-laden, and tentative NOS, and the distinction between observation and inference as evident in the following excerpts from student papers:

> Jessica and her father's theories about the outside world could never be more than tentative . . . This is the case in science today. Since we cannot directly see the atom or black holes, our inferences about these

> concepts are tentative even though they are as reasonable as possible given the evidence. (G13, first reflection paper).
>
> One of the aspects of the nature of science that this story illustrates is subjectivity. We interpret things based on what we know. Because if we were born in a cave we would have to infer what was outside the cave from observations, we might not really know what is there, though it would make sense to us. Much of our scientific knowledge today seems to me to come from observing the "shadows on the wall" and maybe what we think we know is really way off. (U19, first reflection paper)

A few participants were successful in mapping relationships between all seven emphasized aspects of NOS and the dialogue between Jessica and her father. One such student, a graduate, chose to represent these relationships in the form of a highly integrated semantic map (see Figure 1).

For the second reflection paper, participants watched Bill Nye the Science Guy "Pseudoscience" episode and responded to the following questions: "Do the ideas that Bill Nye shared in the 'Pseudoscience' episode fit our discussions of NOS? If yes, how? If no, why? In your discussion try to focus on the elements of tentativeness, creativity, observation versus inference, subjectivity, relationships of theory and law, and social and cultural embeddedness of science." Again, in their reflection papers, students focused on the tentative and empirical nature of scientific knowledge and the roles of observation versus inference in the generation of scientific knowledge, as evident in the following representative quotes:

> The episode showed that new evidence can change our view about what we know about science. Bill Nye focused on observation vs. inference, because he pointed out how without direct observation inferences could really be wrong, like with thinking crop circles are created by UFOs. (U18, second reflection paper)
>
> The show really discussed the difference between science and pseudoscience. Real science can be tested. Pseudoscience is not testable. (G5, second reflection paper)

Figure 1.

Student-designed table to contrast her views with the realities of science as given in the "Myth of the Scientific Method and Slippery Debates in the Classroom" reading response.

Misconceptions of Science	Realities of Science
Science is defined as knowledge gained by observation of the present physical world, using the 5 senses.	Science isn't limited to that definition. Science also involves manipulative experiments, reconstructing past events to understand the present, "extensions of the senses" (Instrumentation), as well as many other dimensions used in understanding the physical world
There is one scientific method that is always used by scientists	Many "scientific methods" exist and there is no set way to investigate a problem. What counts is the evidence gathered.
A theory is simply "somebody's idea" of what has happened.	Scientific theories are well established explanations of natural phenomena. They usually have tremendous amounts of supportive evidence.
Theories can be proved true.	Theories can't be proved true. Rather, scientists test predictions derived from a theory and their results either refute the theory or simply strengthen it.
Religion and science can be compared using scientific means.	Religion and science use different ways of "knowing." Religion uses religious texts, prophets, and deity to find absolute truths. Faith, not physical evidence, is often stressed. Science is ever changing and is based on physical evidence. They can't be compared using scientific methods.
Evolutionary theory and religion are incompatible.	The compatibility depends on whether a religion has a literal or nonliteral view of Genesis.

Conceptual Change Intervention

To use a conceptual change strategy to help students improve their conceptions of NOS it was necessary to develop a picture of their current understandings. Questionnaires and pre-instruction interviews were used to identify students' initial understandings of NOS. Students were made aware of their understandings when the instructor of the course listed the conceptions on the overhead and then shared them with the class. Students were then led through several activities to help them recognize their ideas were not sufficient explanations for the elements of NOS emphasized in the course. First, students were presented with an overview of NOS depicting NOS in a manner consistent with reforms (Lederman & Abd-El-Khalick, 1998). Second, students were treated to weekly readings from science and science education literature designed to help them recognize better explanations for NOS than the ones they currently held. In addition to the readings, students were required to submit weekly reaction papers based on the readings that asked them to discuss the readings within the context of their current understandings, with implications for their future teaching placements (See Appendix for reading list). With each reaction paper student responses were paraphrased and shared with the class as a whole the following class session, to continue making students aware of their ideas and developing conceptions. Third, students were exposed to weekly activities designed to confront their current understandings of NOS (Lederman & Abd-El-Khalick, 1998; Abd-El-Khalick, 1999). Discussions ensued following each reading and activity, to allow students to share ideas, and develop new understandings. To check final understandings, all students were given questionnaires and ten students were purposely selected for final interviews to help determine what helped some students develop stronger conceptions than others.

Data Analysis

The second researcher analyzed the data. This approach was undertaken because the first researcher was the instructor in the courses and consequently she might have perceived such data to be partially evaluative.

The NOS questionnaires and corresponding interview transcripts of the 10 randomly selected participants were analyzed and compared to validate participants' responses to the NOS questionnaire. Next, all NOS questionnaires were analyzed to generate pre-instruction and post-instruction profiles of participants' views of the NOS in the two courses. In this analysis, each participant was treated as a separate case. Data from each questionnaire was used to generate a summary of the participant's views.

This process was repeated for all the questionnaires. After this initial round of analysis, the generated summaries were searched for patterns or categories. The generated categories were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data. Moreover, analyses of the cohort participants' second reaction papers were used to corroborate or otherwise modify the views derived from analyzing the NOS questionnaires. Additionally, reaction papers allowed the researchers to generate more in-depth profiles of participants' views. Finally, pre- and post-profiles were compared to assess changes in participants' views. The final post-instruction interview was used to try to discern differences between students who seemed to develop better understandings of NOS from those who seemed to continue to have difficulty in their conceptions.

Results

The following sections elucidate participants' pre-instruction and post-instruction views of the target aspects of NOS. the number following a students' response refers to an individual participant. Table 1 presents a summary of results from the study. The table shows the percentage of students who held adequate views of NOS before and after instruction for each of the elements emphasized in the course.

Pre–instruction NOS Views

Consistent with previous research findings (Lederman, 1992) participants' views harbored several misconceptions about the NOS prior to instruction. No student held adequate views of all elements emphasized in the course, though several did hold adequate views of certain conceptions. The statements quoted below are examples of inadequate responses.

Table 1.

Percentage of Participants with “Adequate” Views of the Emphasized Aspects of NOS

NOS aspect	Pre-instruction	Post-instruction
Empirical	0	25
Tentative	25	60
Creative & imaginative	10	78
Subjective (theory-laden)	25	43
Social & cultural	50	71
Observation vs. inference	10	50
Theories & laws	7	35

Observation versus inference. In response to the question of how certain are scientists about the structure of the atom and the evidence scientists used to derive this structure, only ten percent of the students held adequate views of the difference between observation and inference. Most of the students believed scientists needed to be able to see the atom to develop a model of the structure—that without being able to “see” it through a high-powered microscope they would not be able to develop the model:

> S6: Scientists are very sure of the structure. They discovered it by the use of a microscope.
>
> S12: The structure is very well accepted among scientists. They can see how atoms look with really high-powered microscopes.

Thus, without the ability of tracking the atom through the senses, even the extended senses of the microscope, most students believed the model could not have been able to be developed.

The functions of, and relationship between scientific theories and laws. All students but two subscribed to inadequate notions about theories and laws. Many believed the notion that theories were simply a means to developing laws. Most students believed that with sufficient "proof" theories would develop into laws, which to these students represented the ultimate in scientific knowledge. Thus, the kinds of knowledge explained by theories and laws were not different, just different in terms of the amount of "proof" that supported each. Moreover, this led to the belief that laws were absolute and did not change because they had been "proven" and were the ultimate source of scientific knowledge:

> S2: I think a scientific law is a theory that has been proven and found to be constant and repeatable. The law of gravity is an example.

Other students believed that theories were a type of knowledge that was somewhat weaker, that did not have enough "proof," when in fact, theories have much supporting evidence. Theories were simply noted as guesses that had not been proven or disproven:

> S4: A theory is one's belief. Freud has a theory that everything about us relates to something sexual. Theories aren't sure things and we don't have to believe them. On the other hand, a law is written and proved. The law of gravity—what goes up must come down.

> S9: A theory is only a theory, an idea that scientists come to after forming a hypothesis and collecting information. A law has been tested over and over and proven to be true each time.

The empirical and tentative NOS. No students held adequate views of the empirical NOS. No students recognized that the empirical NOS sets science apart from other disciplines. Most students noted that science was a method for doing things or proving things:

> S25: Science requires you to follow a step-by-step format to get results.

> S8: Science is based on experience using the right method.

Similarly, the great majority (75%) held inadequate views of NOS as tentative. Many believed that scientific laws are proven and do not change. Many thought theories did change, but only because they changed into laws, or because of new technologies which allowed us to see things differently.

This "seeing" relates back to the belief that "seeing is knowing" and that is how scientific knowledge is developed, not through inferences made of observational data.

> S1: Theories can change all the time until the scientist proves it to be a law.
>
> S12: Of course theories can change. They are not laws.

The creative and imaginative NOS. The majority of participants (90%) did not demonstrate adequate understandings of the role of human inference, imagination, and creativity in generating scientific claims. Most participants believed that "seeing is knowing," and did not appreciate the creative work in searching for patterns in data or developing models and theories. Students thought of science as boring and repetitive because they thought science had to proceed through a specific method or procedure.

> S5: Scientists do not use creativity or imagination while collecting data. They have to use one set method so that all scientists can do it and get the same results.

For those students who did believe that scientists used creativity they believed more of the role of inventiveness of new items, or making presentations of their results, not of inventing ideas or models and explanations:

> S6: They use their creativity in presenting their ideas and theories to the public.
>
> S10: Scientists use their creativity and imagination to develop new technology, like microscopes, to help us learn more about the world.

Students often stated scientists could be creative in designing a study, but must remain objective and thus non-creative when interpreting and carrying out designs:

> S20: Scientists should not be creative because they will change the variable. They have to follow the right method in order to be objective.
>
> S25: Just forming a hypothesis is creative, but I would hope that once a way to test the hypothesis was decided creativity would give way to unbiased observation.

The subjective, and social and cultural NOS. About three-fourths (75%) of the participants did not recognize the role that background knowledge and training played in the scientists' development of scientific knowledge. Participants believed scientists were naturally objective to give the best and fairest results:

> S3: While other subjects might embrace different viewpoints and opinions, science tries to eliminate all this when interpreting results.
>
> S24: Knowledge in science comes from objective observations.

Objectivity was claimed to be guaranteed through the use of a set of procedures that students noted as "the scientific method" which they also believed limited science to being a boring discipline.

> S21: Knowledge comes from adherence to the scientific method that enables us to have an objective picture of the world.
>
> S23: The scientific method that we all know was developed to help us get objective scientific information and knowledge.

Students were also limited in their views of social and cultural influences on the interpretation of data. When students were asked to explain a scientific controversy half of the students described the reason as being to lack of a full set of data. They dismissed possible influence of background knowledge and cultural background. If they did note an influence of background knowledge, they did relate it to purposeful interpretation of data to support claims they believed should be the correct explanations.

> S25: It is like the parable of the three blind men trying to describe an elephant from a different body part—if all the scientists had enough data they would come up with the same results.
>
> S12: Scientists can be biased and be looking for specific findings and they manipulate experiments and data to accommodate their hypotheses.

Post–instruction NOS Views

As can be seen in Table 2, there was a substantial increase in participants who held adequate views of the target aspects of NOS at the conclusion of the study. While there were observed changes in each aspect of NOS targeted, the observed changes were not consistent across the investigated NOS aspects. Changes in participants' views were particularly pronounced with regard to the tentative NOS, the distinction between observation and inference, and the social and cultural NOS. Changes were also evident in participants' views of science as empirical, and subjective (theory-laden), and the relationship between theory and law. These changes were less pronounced.

Table 2.

List of Course Readings to Help Students Confront Their Understandings of NOS

Class Session	Reading and Author
4	McComas, B. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 9,6* 10-16.
5	Lederman, N. G., Farber, P. L., Abd-El-Khalick, F. S, & Bell, R. L. (1998). The myth of the scientific method and slippery debates in the classroom: A response to McCreary. *The Oregon Science Teacher,* 24-27.
6	Lederman, N. G., Abd-El-Khalick, F. S., & Bell, R. L. (in press).If we want to talk the talk, we must also walk the walk: The nature of science, professional development and educational reform. In J. Rhoton & P.S. Bowers (Eds.), *Issues in science education* (2nd ed.). Arlington VA: National Science Teachers Association.
7	Penrose, R. (1994). Prologue. *Shadows of the mind: A search for the missing science of consciousness.* New York: Oxford University
8	Sagan, C. (1996). The Most Precious Thing. In *The demon-haunted world: Science as a candle in the dark.* New York: Random House.
8	Hoffman, R. (1993). For the first time, you can see atoms. *American Scientist, 81,* 11-12.

The following sections describe participants' post-instruction views. Some participants held inadequate views of the target NOS aspects at the conclusion of the study. The quotes presented are meant to illustrate views that were considered adequate.

Observation versus inference. Compared to only 10% of the participants who held adequate views of the difference between observation and inference prior to the study, 50% expressed adequate views at the conclusion of the study. Several students specifically mentioned the Rutherford's Enlarged activity that was demonstrated in class as having helped them to develop better understandings of the inferential NOS. The participants appreciated the inferential nature of atomic structure.

> S20: Scientists have observed evidence and inferred what it means. They have created meaning from the evidence they have observed.

> S7: They were not able to see atoms, but could see the path of the atoms, inferring the atoms' shapes.

Unfortunately, some participants seemed to gain an understanding that the development of the model of the atom was by virtue of inference through the STM microscope. They appeared to gain this misunderstanding from a faulty interpretation of the Hoffman (1993) reading:

> S4: Scientists can never be sure about the structure because you cannot see them. How ever, STM-microscopes can be used to derive a round-about picture of an atom's structure.

Others combined results obtained from the Rutherford's Enlarged (Abd-El-Khalick, 1999) with the Hoffman (1993) reading and concluded:

> S16: Scientists use an amazing STM microscope to get a "picture" of atoms by scanning the item with particles. When they see the particles bounce they can infer the shape of the atom because the atoms only go through the parts where the atom is not in the way.

The functions of, and relationship between scientific theories and laws. At the beginning of the study most participants held a hierarchical view of the relationship between theories and laws. At the final questionnaire and interview 35% of the participants adopted the view that scientific theories and laws were different kinds of knowledge and that one did not develop in the other:

> S17: Laws identify or describe relationships between observations such as gravity. A scientific theory is an inferred explanation for the observation, like kinetic molecular theory.

> S8: Scientific theory is an explanation made after observations. A law is a description of observable situations in an experiment.

Indeed, participants also seemed to recognize the importance of teaching the difference between theories and laws to help their own students develop an adequate understanding of science:

> S10: We teach theories because they are scientifically sound. They are inferences based on much evidence. Students can learn about creating theories as part of science, but the theories must be based on data.

The empirical and tentative NOS. Prior to the study no participants had an inclination to report that science differed from other disciplines, such as art, in the manner of being empirical. At the conclusion of the study 25% of the participants reported that science differed from art because scientists based their interpretations of the world on evidence. However, they still recognized the role of the scientists in interpreting that evidence, noting that scientists needed to be "very creative while collecting data and interpreting data." (S25, post-questionnaire).

There were also gains in participants' views of the tentative NOS. At the conclusion of the study 62% of the participants stated more adequate views of the tentativeness of scientific knowledge. Students most often reported that the reason for a change in a scientific view was due to new evidence, and that creates a better explanation:

> S11: Because theories are an attempt to explain scientific law they sometimes change if new evidence is found that refutes the current theory, or that better explains the law.

Participants expressed the view that all scientific knowledge was subject to change, and could change via a modification of current ideas, or the replacement of current ideas with ones based on better evidence:

> S27: It depends on the situation what kind of change. With some things it is a 180 degree change, but other times ideas are just added or modified. Scientists change their ideas with new evidence or reinterpreting the evidence they already have (post interview).

The creative and imaginative NOS. A full 78% of the participants exited the course with more adequate understandings of the role of creativity and imagination in science. They believed that science, like art, required creativity and imagination:

> S26: Science and art both take creative minds to come up with new and interesting ideas of our world.
>
> S12: There is really a lot of room for creativity in science. I always thought science was rigid and step-by-step before, but now I realize that scientists use lots of creativity to interpret their data. Seeing the creativity involved in science allows me to enjoy it more.

Additionally, participants interpreted "creativity" and "imagination" as ways of developing ideas, not just ways of developing new products, as were their statements pre-instruction:

> S11: Scientists need to be creative to elaborate a representation of ideas they have developed. They have to use imagination to develop those ideas from their explorations.
>
> S13: They will never be able to collect enough data to form a perfect picture of their investigation. They must collect data and use their imaginations and creativity to interpret that data to make the best inferences for their explanations.

The subjective, and social and cultural NOS. There was positive change in explanation for the participants' views of the subjective (theory-laden), and social and cultural NOS. Participants increased from 25% to 43% exhibiting adequate explanations of the subjective NOS, and at the conclusion of the study 71% of the participants explicated adequate understandings of the social and cultural NOS. These participants noted that scientists' prior knowledge, personal backgrounds, and viewpoints, and other "human" elements influenced how they interpreted data:

> S11: Because the NOS is subjective and creative it would be surprising if scientists came up with the same theory based on the same data. They simply have different interpretations of the data based on their knowledge and backgrounds.
>
> S5: Each one has different interpretations of the data. Even when they can test their theories, if all the theories make the same good explanation of the event, just like when we did the model of the strings and tubes, all the theories are good and you really don't know which theory is most accurate unless you can find more evidence.

Discussion and Implications

Consistent with research on science teachers' views of NOS (e.g., Abd-El-Khalick & Boujaoude, 1997; Aguierre et al., 1990; Bloom, 1989; Carey & Strauss, 1968, 1970; King, 1991; Pomeroy, 1993), participant preservice elementary teachers held naïve views of many of the investigated aspects of NOS at the beginning of the study. The majority of participants believed that the use of a single scientific method or other sets of orderly and logical steps characterize science. Almost all participants explicated inadequate views about the relationship between theories and laws. Many believed that laws are "proven" to be true while theories are not "proven." The others believed in a hierarchical relationship between theories and laws whereby theories become laws with the accumulation of supportive experimental results. The view that scientific laws can be "proven" and/or are not liable to change indicated that participants thought that scientific knowledge is absolute. Moreover, the majority of participants did not demonstrate adequate understandings of the role of human inference, imagination and creativity in generating scientific claims, or the subjective (theory-laden) nature of science. In this regard, participants failed to recognize the fact that scientists' disciplinary training and commitments, as well as their personal experiences, preferences, and philosophical assumption do influence their work.

The results of this study indicated that the conceptual change reflective activity-based approach to NOS instruction in this science methods course was "effective" at enhancing participating teachers' views. Participants made substantial gains in their understandings of the target aspects of NOS. Additionally, it was evident that the ideas presented in the course were surprising to the participants, in a way that their ideas were confronted. Whether or not they are able to fully remember and use their newly adapted ideas, they will likely be able to acknowledge that science is different, and "better" than what they had previously thought.

Unlike the previous study (Akerson, Abd-El-Khalick, & Lederman, in press), most participants improved and showed substantial change in their views of the relationship between theories and laws or their absolutist views of scientific knowledge. As was previously found, however, participants made differential gains in their changes of idea related to the targeted aspects of NOS. It was apparent from the reaction papers that students were genuinely struggling with adapting the new ideas within their current frameworks of what is "science" to them. Many of the ideas were surprising to them, which enabled them to confront their own ideas, but as would be found in any conceptual change study, lasting conceptual change is difficult. The participants themselves indicated they felt their new ideas were on shaky ground, and that without continual effort at managing these ideas they believed the new ideas would not "stick." One participant, in a post interview, even suggested a second semester of science methods, during which preservice teachers could learn more science content and practice their knowledge of NOS in the context of those investigations.

Indeed, the profile of participants' views at the conclusion of the study were similar to those of previous studies (e.g., Akerson, Abd-El-Khalick, & Lederman, in press), calling into question whether a conceptual change strategy is the most appropriate for developing NOS ideas over the course of a one semester science methods course. Perhaps the reflective, explicit component is more influential in developing the participants' ideas toward accepted conceptions. In post-instruction interviews participants indicated that the single item that most influenced any changes in their ideas was reading the papers and writing the reflection papers. Though they stated they didn't always enjoy writing the reflection papers, it forced them to think about the ideas and interpret them for themselves.

Though disappointing, it was not surprising that participants did not develop fully adequate, nor internally consistent and cohesive ideas of NOS during the course of this study. Results of this study are consistent with past research on alternative conceptions (Driver,Guesne, & Tiberghien, 1985 ; Posner, et al., 1982), and show the tenacity of deeply held personal ideas. All participants in this study indicated that their ideas developed over their careers as elementary and high school students, and in fact, one student admitted to her idea of the scientific method being so ingrained by previous teachers that in one high school class that did not use the "scientific method," she looked it up and prepared all lab reports according to that format. While students appeared to be relieved that some of the ideas that had previously held as absolute truth were in fact myths, they also seemed concerned that they may not be able to adequately recall and relate those ideas to their own students.

In addition, it may not be possible to help all, or even most, preservice elementary teachers to have an adequate, consistent framework for thinking about the target aspects of NOS in a one semester science methods course, given that many other topics must be covered in such a course. It is our recommendation that a two–semester science methods course sequence would more adequately prepare elementary science teachers in many areas. The first semester could be designed similar to the course examined in this study—an overview of science teaching and NOS presented in an explicit, reflective manner. The second semester would include application of target aspects of NOS in an inquiry setting, along with preservice teachers designing and teaching lessons to elementary students, with the requirement of including aspects of NOS in lesson plans and lessons, giving them some of the experience they will need to appropriately instruct their own future students. Given appropriate funding and support, it is our intention to explore this two-semester avenue as a future study for developing elementary teachers' views of NOS.

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Appendix A
Nature of Science Questionnaire

1. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of atoms? What specific kinds of evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

Appendix B
Post-Instruction Interview Questions

1. What can you tell me about NOS? Did anything you learned about NOS surprise you?
2. What specific activities/readings helped you develop your ideas about NOS?
3. What made sense to you from among the ideas about NOS we introduced in class? Why? What did not make sense? Why?
4. Can you explain to me a bit about observation and inference? Please give me an example of an observation and inference. (For students who seem to have an erroneous view: In your Penrose reaction paper you stated that Jessica's observation of the boulder in the cave led her to an inference that it may fall. Can you tell me why you called that an example of observation and inference? What difference can you see between that example and the example of the Rutherford's Enlarged activity?)
5. How have your views of science changed or developed over the course of this semester? In what ways?
6. How do scientists generate scientific claims? What sets science apart from other disciplines, such as religion or philosophy?
7. What is a scientific model? How can scientists develop models of things they cannot even see?
8. Do scientists change their claims about nature? Given an example. What do you mean about change here? Do you mean "new things are added to existing claims" or do you mean that "some claims are thrown away and replaced by new ones?" What can cause scientists to change their ideas and claims about something?
9. What are some thoughts you have about helping your own students overcome their "myths of science" they may have developed in their school years? Or how can you help prevent your students from developing such myths?
10. Is there anything more you would like to tell me about NOS or teaching NOS?

IMPROVING ELEMENTARY TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE IN THE CONTEXT OF A SCIENCE CONTENT COURSE

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During the past 85 years, almost all scientists, science educators, and science education organizations have agreed upon the objective of helping students develop adequate conceptions of nature of science (NOS) (Abd-El-Khalick, Bell, & Lederman, 1998). Presently, and despite their varying pedagogical or curricular emphases, agreement among the major reform efforts in science education (e.g., American Association for the Advancement of Science [AAAS], 1990, 1993; National Research Council [NRC], 1996) seems to center around the goal of enhancing students' conceptions of NOS.

However, research has consistently shown that K-12 students have not attained the desired understandings of NOS (Duschl, 1990; Lederman, 1992). Similarly, science teachers were found to harbor several naïve views of NOS (e.g., Abd-El-Khalick et al., 1998; Billeh, & Hasan, 1975; Bloom, 1989; King, 1991). To mitigate this state of affairs, several attempts were undertaken to improve science teachers' conceptions of NOS (e.g., Akindehin, 1988; Billeh, & Hasan, 1975; Haukoos & Penick, 1983, 1985; Ogunniyi, 1983; Olstad, 1969; Scharmann & Harris, 1992). In a review of these attempts, Abd-El-Khalick and Lederman (1998) concluded that researchers were generally not successful in helping teachers develop understandings that would enable them to "effectively" teach about NOS. Nonetheless, Abd-El-Khalick and Lederman noted that an explicit reflective approach to enhancing teachers' NOS views was relatively more "effective" than an implicit approach that utilized hands-on or inquiry-oriented science activities lacking explicit references to NOS. In this regard, using an explicit reflective approach (e.g., Dickinson, Abd-El-Khalick, & Lederman, in press;

Shapiro, 1996) was more successful in enhancing elementary teachers' NOS conceptions than implicit approaches (e.g., Barufaldi, Bethel, & Lamb, 1977; Riley, 1979).

These latter explicit attempts (e.g., Dickinson et al., in press; Shapiro, 1996), nonetheless, were undertaken in the context of elementary science methods courses. Learning about NOS in this context may impede the translation of prospective teachers' acquired NOS conceptions into their classroom practice. Research has indicated that the translation of teachers' conceptions of NOS into their instructional practice was, at best, limited (Abd-El-Khalick et al., 1998; Abd-El-Khalick, Lederman, & Bell, 1998; Aguirere, Haggerty, & Linder, 1990; Brickhouse & Bodner, 1992; Briscoe, 1991; Lederman, Schwartz, Abd-El-Khalick, & Bell, 1999). Such translation was found to be neither direct nor "automatic," but rather mediated by a host of constraining factors. Among these factors was learning about NOS in the context of science methods courses as opposed to science content courses (Abd-El-Khalick et al., 1998).

In our own research (Abd-El-Khalick et al., 1998; Lederman et al., 1999), preservice secondary science teachers often complained that NOS instruction and activities they experienced in science methods courses did not help them address NOS instructionally during student teaching. They attributed this lack of utility to the fact that that instruction and those activities were embedded in science teaching methods rather than science content. These findings were consistent with research on situated cognition (e.g., Brown, Collins, & Duguid, 1989). It seemed that the different contexts within which our participant teachers learned about NOS (science methods courses) and in which they were expected to apply their knowledge (science content courses) compromised their ability to translate their conceptions into actual classroom practices. A possible way to ameliorate this constraining factor and enhance the translation of teachers' NOS views into instructional practice would be to develop teachers' NOS understandings in the context of science content courses.

NOS

Typically, NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). These characterizations, nevertheless, remain fairly general, and philosophers of science, historians of science, sociologists of science, and science educators are quick to disagree on a specific definition for NOS. Such disagreement, however, should not be surprising given the multifaceted and complex nature of the human endeavor we call "science." Moreover, similar to scientific knowledge, conceptions of NOS are tentative and dynamic: These conceptions have changed throughout the development of science and systematic thinking about its nature and workings (Abd-El-Khalick & Lederman, 1998).

However, at one point in time and at a certain level of generality, there is a shared wisdom (even though no complete agreement) about NOS amongst philosophers, historians, sociologists, and science educators. For instance, it would be very difficult to reject the theory-laden nature of scientific investigations, or to defend a deterministic/absolute or empiricist conception of NOS in the 1990s. Moreover, at such a level of generality, some important aspects of NOS are virtually non-controversial. Such NOS aspects have been advanced in recent reform documents in science education, such as *Science for All Americans* (AAAS, 1990, especially chapter one) *and National Science Education Standards* (NRC, 1996, especially chapter six).

In the present study, six of these aspects that we believe are accessible to K-12 students and relevant to their daily lives, were adopted and emphasized (also see Abd-El-Khalick et al., 1998). These aspects are that scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), theory-laden (subjective), and partly the product of human inference, imagination, and creativity (involves the invention of explanations). Two additional important aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws.

Purpose

The present study was exploratory and interpretive in nature. The purpose of the study was to assess (a) the influence of an explicit, activity-based reflective approach, implemented in the context of a science content course, on elementary teachers' views the aforementioned aspects of NOS, and (b) the ability of elementary teachers to apply acquired NOS understandings, if any, in the context of "familiar" as compared to "unfamiliar" science content. "Familiar content" refers to subject matter covered in the investigated science content course.

Method

Participants

Participants were all 30 female elementary education majors enrolled in a semester-long physics course for elementary teachers offered at the Department of Education at an American University in a Middle Eastern country. Participants' ages ranged between 17 and 22 years with an average of 19.8 years (standard deviation = 1.4 years). Of the participants 10 (33%) were sophomores, 12 (40%) were juniors, and 7 (27%) were seniors. All participants were pursuing a BA in elementary education and had limited science content backgrounds.

The Intervention

The intervention was undertaken in the context of the aforementioned physics course, which is taught by the author. The course is mathematics-free, emphasizes conceptual understanding, and utilizes a variety of instructional approaches including hands-on inquiry activities. The content covered is minimal and includes the atomic structure of matter; the physical characteristics of solids, liquids, gases, and plasmas; heat, temperature, and heat transfer; and basic thermodynamics.

Over the course of five instructional hours at the beginning of the course, a set of five generic activities and two readings were used to explicitly introduce participants to the six target aspects of NOS. Detailed descriptions of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998). A whole-class discussion followed each activity and involved students in active discourse concerning the presented NOS aspects.

The NOS framework developed at the course outset became a theme that permeated all following instruction and discussions. Whether participants were engaged in learning science content or inquiry skills, the instructor prompted them to reflect on their experiences from within the developed NOS framework. Participants were often asked to elucidate how the target NOS aspects were manifest in the science content discussed or activities conducted throughout the course.

Procedure

An eight-item open-ended questionnaire (Abd-El-Khalick, 1998) was used to assess participants' views of the aforementioned NOS aspects prior to and at the conclusion of the course. Six of the items were generic. The remaining two were content-specific: One item was related to "familiar" content, that is content covered in the investigated science course (atomic structure), and the other to "unfamiliar" content (extinction of the dinosaurs).

Given the present study's concern with the meanings that participants ascribed to the six emphasized aspects of NOS, it was imperative to avoid misinterpreting participants' responses to the questionnaire. As such, individual semi-structured interviews were used to establish the validity of the questionnaire by insuring that the researcher's interpretations corresponded to those of participants. The interviews also aimed to generate in-depth profiles of participants' NOS views. Twelve randomly selected participants (40% of all participants) were interviewed. Six participants were interviewed at the beginning of the study and six at its conclusion.

During the interviews, which were conducted by the author, participants were provided with their pre- or post-instruction questionnaires and asked to read, explain, and justify their responses. Follow-up questions were used to clarify participants' responses and further probe their lines of thinking. All interviews, which typically lasted about 45 minutes, were audio-taped and transcribed for analysis.

Data Analysis

The author analyzed the data. A graduate student in science education conducted a blind round of analysis. The two analyses were compared and differences were resolved by consensus. This procedure was undertaken to insure the validity of the analysis since the author was the course instructor and could have perceived the data as partially evaluative.

Initially, the author analyzed the pre-instruction NOS questionnaires of the six randomly interviewed participants to generate a profile of their NOS views. The graduate science education student conducted a similar analysis using these six participants' corresponding interview transcripts. The independently generated profiles were then compared to insure the validity of the questionnaire. This analysis indicated that the researcher's interpretations of participants' NOS views as elucidated in the questionnaire were congruent to those expressed by participants during individual interviews. The same procedure was repeated using the post-instruction NOS questionnaires and corresponding interview transcripts of the other six interviewees and resulted in similar congruency of the independently generated NOS profiles. This congruency allowed the researcher to proceed with data analysis.

Next, all NOS questionnaires were analyzed to generate pre- and post-instruction profiles of participants' NOS views. In this analysis, each participant was treated as a separate case. Data from each questionnaire was used to generate a summary of the participant's views. This process was repeated for all questionnaires. The generated summaries were searched for patterns or categories, which were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data.

Pre- and post-profiles were compared to assess changes in participants' NOS views. Additionally, participants' responses to the two content-specific items prior to and following instruction were compared and contrasted. This latter analysis aimed to assess whether the content in which the presented NOS ideas were embedded was restrictive or whether students were able to generalize their NOS understandings to other science content areas not covered in the course.

It should be noted that data analyses primarily focused on participants' pre– and post–instruction views of the six target NOS aspects. However, given the interpretive nature of this investigation, analyses was kept fairly open and emerging patterns in the data were pursued. These patterns led to the development of several emergent hypotheses, which were further tested by reference to the data in search of confirming or negating instances. As will be explicated below, a few of these emergent hypotheses were substantiated by further analyses and resulted in major re-conceptualization of the results of the present study.

Results

At the outset of the study, a large majority of participants held naïve conceptions of the six target NOS aspects. The naïve conceptions of a majority of these latter participants seemed to fit into a "scientistic" worldview. On concluding the study, several favorable changes were evident in participants' views of the target NOS aspects. To the extent that the present study was concerned with improving participants' conceptions of some specific aspects of NOS, the explicit reflective NOS instruction employed to achieve that end was substantially successful. However, a disconcerting pattern characterized participants' post-instruction overarching framework for science. A considerable portion of the participants seemed to have shifted from a "scientistic" to a "naïve relativistic" worldview. Additionally, analyses of participants' post-instruction views showed that they were less successful in applying their newly adopted conceptions of the target NOS aspects in the context of "unfamiliar" subject matter (extinction of the dinosaurs) as compared to more familiar subject matter (atomic structure), which was explored in the investigated course. In the following sections, the letter "P" followed by a numeric is used to refer to individual participants.

Participants' Pre-instruction NOS Views: A Scientistic Worldview

In our previous research studies (e.g., Abd-El-Khalick, 1998; Abd-El-Khalick et al., 1998; Dickinson et al., in press), prospective secondary science and elementary teachers held naïve views of several important aspects of NOS. These views, however, were mostly compartmentalized and lacked an overarching framework. This was not the case for a majority of participants in the present study whose naïve views of the six target NOS aspects seemed to fit into a broader "scientistic" worldview.

Participants were asked what is science and how it differs from other disciplines of inquiry such as philosophy and religion. In their response to this and other items on the open-ended questionnaire, about 60% of all participants, elucidated a "scientistic" worldview. According to this worldview, scientific knowledge is not tentative. Rather, science is an objective endeavor concerned with the generation of "certain" or "true" knowledge about the natural world:

> The term science . . . denotes only knowledge which is sure, certain, objective, quantitative and organized or formulated into laws. (P8, pre-questionnaire)

> Philosophy . . . doesn't give answers . . . On the other hand, in science there is only one proved answer to every question. It is a certain study. (P23, pre-questionnaire)

According to about 67% of all participants, such "certain" or "true" knowledge is achieved through the use of the "Scientific Method" (27%) and/or the reliance on neutral, objective observations of the natural world (40%):

> Scientists start by observing, then (1) they form questions about our physical world, (2) they test hypothesis made to answer these questions (using the systematic scientific method), (3) they come up with conclusions about those questions. These conclusions become facts or truths which are added to the body of knowledge. (P12, pre-questionnaire)

> Scientific knowledge is true . . . To get to say this or back this up, all we need to do is if we carefully study the steps of the scientific method which are considered the scientists' Bible . . . All this knowledge is based on observation, which involves close monitoring and is based on givens perceived by the senses, and which therefore does not have any personal input. (P3, pre-interview)

The above representative quotes serve to elucidate many participants' belief in the existence of a universal "Scientific Method" or a single set of orderly steps for "doing" science. Additionally, these quotes represent naïve conceptions of the theory-laden and empirical NOS, whereby "certain" knowledge is generated by making theory-free or neutral observations of natural phenomena. Indeed, a majority of participants (63%) noted that science relies solely on observations of the natural world (or "facts") to the exclusion of other more subjective human elements, such as beliefs and opinions:

> The major difference between science and religion is that the first is based on facts of knowledge whereas the later on beliefs, and science in no way can be based on beliefs. (P8, pre-questionnaire)

> Religion and philosophy might include a little bit of opinion or belief, while science has no relation with points of view and with personal subjective opinion but with truths. (P17, pre-questionnaire)

Only a small minority of participants (10%) expressed more informed views of the scientific endeavor as evident in the following quote:

> Science is the art of seeking knowledge using systematized ways which involve data collection, formulation of concepts and verifying them. Science is an art because it requires creativity, imagination and personal input . . . Scientific disciplines as well as other disciplines of inquiry share common grounds; all continuously strive to report facts, address a certain phenomena and explain it. However, the basic difference is in the methodology followed by each . . . For example, science relies on observations to explain the "how" and "why" of things. (P26, pre-questionnaire)

Participants' belief in the certainty of scientific knowledge was also evident in their conceptions of scientific theories and laws. When asked to articulate the difference between theories and laws, 60% of all participants noted that scientific laws were "fixed," "certain," or "unchangeable," while theories were subject to change:

> A scientific theory is a hypothesis that was tested but doesn't have clear evidence. So, a scientific theory is subject to changes. But a law is proven true and never changes. (P19, pre-questionnaire)

Additionally, 23% of all participants noted that scientific theories do not change. For these participants "theories are not meant to change or else we won't have a base for science. Theories take a lot of time and hard work . . . to be accomplished in order to stay as such and not to change" (P1, pre-questionnaire).

However, the greater majority of participants (77%) noted that scientific theories do change over time due to new "facts," "discoveries" or "advances in technology." This pattern could be taken to indicate that many participants held a tentative view of scientific knowledge. A closer examination of participants' views, nonetheless, indicates that this belief actually fits into a misconceived notion of the workings of the scientific enterprise. Participants seemed to endorse a tentative view of scientific theories not because they ascribed to a non-absolutist view of science, but because of holding naïve conceptions of the nature of scientific theories and their relationship to scientific laws.

About 76% of all participants did not hold views of scientific theories as internally consistent, highly substantiated systems of explanations that account for huge sets of empirical observations. Rather, these participants believed that scientific theories changed because they were unsubstantiated "guesses" or "opinions":

> Theories change because this is what they are; a generalized opinion. But that opinion is not backed up by proof or data. (P11, pre-questionnaire)

> I believe that theories might change since they are without sufficient evidence or proof. After all, a theory is basically a reasonable speculation or a scientific analysis. (P17, pre-questionnaire)

For these participants, theories are not espoused or legitimate scientific products. Rather, theories are an intermediary step toward formulating "true" or "fixed" scientific laws. In a sense, scientists advance "theories" or "guesses," which they subject to empirical testing for the purpose of either "proving" them correct and admitting them into the scientific corpus as scientific laws or "proving" them wrong and discarding them. Indeed, about 76% of all participants ascribed to this naïve hierarchical view of the relationship between theories and laws whereby theories become laws if they are "proven":

> When a scientist develops a theory, he uses experiments and does researches to see if his theory is 100% true. If it is then it becomes a scientific law proven scientifically. (P5, pre-questionnaire)

Only 17% of all participants expressed more adequate views of the relationship between theories and laws. These participants noted that theories and laws perform different "functions" in science and did not assign one as more "certain" than the other:

> A scientific theory differs from a scientific law. A law describes a sequence of events invariable under the same conditions. For example, the law of gazs [sic] which is usually done under certain conditions. A theory is a proposed explanation . . . of what is being seen about certain facts, such as kinetic molecular theory. (P13, pre-questionnaire)

Consistent with their views of scientific theories as "guesses" that could be dismissed or could be laws-in-the-making, a large majority of participants failed to explicate informed conceptions of the predictive and explanatory functions of scientific theories or their function in generating and guiding fruitful lines of investigation. Indeed, only 20% of all participants explicated more informed views of the nature of scientific theories and their explanatory and/or predictive function:

> Scientists build theories or theoretical models such as kinetic molecular theory to make it possible for us not only to understand the behavior of gases but to explain and predict as well the values of such experimentally measurable quantities such as pressure, volume, and temperature. (P26, pre-questionnaire)

Also consistent with a "scientistic" worldview, whereby "seeing is knowing," the majority of participants failed to recognize the inferential nature of scientific constructs and claims. These participants did not explicate an understanding of the crucial distinction between inference and observation, or between a claim and the evidence supporting that claim. One item on the open-ended NOS questionnaire asked participants whether scientists were certain about the structure of the atom and what kind of evidence the respondent believed scientists used to derive that structure.

Sixty percent of participants noted that scientists "are 100% sure of the structure of the atom" (P23, pre-questionnaire). A majority of these participants believed that scientists used high-powered or electron microscopes to "observe" the structure of atoms:

> By using an electron microscope they [scientists] knew that an atom is a central nucleus composed of protons (positively charged particles) and neurons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. (P5, pre-questionnaire)

Only nine participants (30%) expressed more informed views regarding atomic structure. These participants noted that such structure is tentative and that scientists used indirect evidence to derive a "model" or "representation" of how an atom might look like:

> An atom is a hypothetical particle of matter, a model, composed of protons, neutrons and electrons . . . I don't think that scientist are one hundred percent sure about its structure. However, they did a lot of studies based on the interaction of different elements and the interaction of the atom's components like with electrical fields. (P22, pre-questionnaire)

That the majority of participants lacked adequate conceptions of the inferential nature of scientific claims was also evident in their responses to the questionnaire item related to the controversy over the cause of the extinction of dinosaurs. This item presented respondents with the controversy and outlined the two most prominent hypotheses (the extraterrestrial impact hypothesis and the volcanic hypothesis). Respondents were then asked how was it possible for scientists to reach two different conclusions regarding the dinosaur extinction even though they had access to and used the same set of data. As will be noted below, responses to this item also served to elucidate participants' naïve conceptions of the theory-laden NOS.

Consistent with an overarching "scientistic" view, the majority of participants did not seem to have internalized that scientists almost always have to go beyond the available data using their creativity and imagination to provide plausible answers to their questions. And even though such answers have to be consistent with the available evidence, they are nevertheless necessarily theory-laden. In other words, scientists' theoretical and disciplinary commitments as well as their training, prior experiences and expectations do influence their *interpretation* of the available evidence and consequently the kind of answers or inferences they construe as the most plausible or valid.

Alternatively, a majority of participants dismissed the dinosaur extinction controversy as non-fruitful because scientists will simply "never know what happened." Again, given that "seeing is knowing," about 30% of participants believed that several hypotheses are possible because "scientists had no written record or witnessed evidences of what caused the extinction" (P3, pre-interview). So, "the reason for all these answers is that this [extinction] happened a very long time ago, at a time when no one was there" (P14, pre-questionnaire). Along similar lines of reasoning, an additional 33% of participants attributed the controversy to the fact that "the data available is very meager and does not give them [scientists] definite conclusions" (P23, pre-questionnaire), the implication being "when scientists gather enough observations, they will be able to prove one conclusion to be right and the other will be wrong" (P30, pre-questionnaire). As such, these latter participants seemed to harbor a simplistic inductive view whereby conclusions directly emerge from collated evidence.

Only 20% of all participants elucidated more adequate views of the inferential and theory-laden NOS in the context of discussing the extinction controversy. Some of these participants noted that both hypotheses or "conclusions" were consistent with the available evidence. Others noted that scientists interpreted the evidence differently or assigned more weight to a subset of the evidence because of their different backgrounds or theoretical frameworks:

> Scientists interpret things differently. Also their believes influence their way of thinking and therefore influence their theories. While one might strategically depend on certain evidence to support his/her theory, the other will give more weight to other parts of the evidence according to his/her theory. This could work as long as the conclusion does not contradict the evidence they have. (P15, pre-questionnaire)

Finally, in the scheme of science endorsed by a majority of participants, imagination and creativity were not assigned a central role. These participants did not ascribe to the view that science is an imaginative and creative endeavor in the sense that scientists use their imagination and creativity to invent constructs, models, theories, and explanations to account for empirical observations and patterns in observable phenomena. Indeed, a small minority of participants (17%) noted that scientists do not use imagination and creativity in their investigations because science is "objective" and only concerned with "facts":

> Scientists do not use their imagination or creativity since they should deal with any event or object of study objectively so that they formulate laws and theories. (P19, pre-questionnaire)

To be sure, a large majority of participants (83%) indicated that scientists use their imagination and creativity when conducting scientific investigations. However, these participants' views of this NOS aspect were mostly naïve. Forty percent of these latter participants noted that scientists' use of imagination and creativity is limited to the planning and design stages of investigations because after these initial stages, scientists have to use systematic procedures to generate knowledge. These procedures, it seems, do not have room for imaginative and creative input:

> Yes. Scientists use their creativity and imagination while planning and designing their experiment. Once they plan the investigation, collecting data and the stages following that is a matter of following systematic scientific methods and processes. (P12, pre-questionnaire)

> Yes, scientists do use their imagination and creativity to some degree maybe in planning and designing. But I don't think they use their creativity in data collecting and analyzing and in making objective conclusions. (P22, pre-questionnaire)

An additional 23% of participants used the terms "imagination" and "creativity" to refer to aspects of scientists' work that are not related to the creative act of inventing theoretical entities or explanations. These participants used the terms to refer to "creative" ways that scientists' use to present their work to the public, or to the invention of useful "gadgets" that help scientists in their investigations:

> Scientists use imagination and creativity. Of course they do not change the shape of the theory like a sculpture changing a stone to a woman. They sure do use their creativity and imagination both together in order to make things simple for simple people like us. Ex: If the research is about planets, each one will think of a practical example, one could choose a big ball, another could choose mini-metallic ball, etc. (P14, pre-questionnaire)

Only a small minority of participants (20%) expressed informed views of the imaginative and creative NOS as evident in the following quotes:

> Scientists use creativity and imagination or else atom models wouldn't be available to us. Creativity and imagination are used at all stages of scientific investigations. (P26, pre-questionnaire)

> I think that they use their creativity and imagination so that they can create a new idea. Scientists collect data and most of the time the data doesn't change, it is the same but scientists always come up with new concepts to explain this data and that's why they use their imagination. (P18, pre-questionnaire)

It should be noted that even though the naïve views of a substantial portion of participants (about 60%) were consistent with a "scientistic" worldview, the conceptions of many others were compartmentalized and inconsistent. In other words, some participants expressed informed views of three or four of the six target NOS aspects, but elucidated naïve views of the remaining aspects. Indeed, only a handful of participants (about 10%) expressed informed views of all six target NOS aspects.

Participants' Post-instruction NOS Views: Favorable Changes, But . . .

Analyses of participants' post-instruction responses revealed several desirable changes in their views of the target NOS aspects. Compared to only 10% at the beginning of the course, 43% of participants expressed more informed views of the scientific endeavor at the conclusion of the study. These participants now viewed science as a creative endeavor aimed at explaining natural phenomena. Many of these participants explicitly noted that scientific explanations are based on evidence but are not absolute or certain, thus expressing more adequate views of the empirical and tentative NOS:

> Science is a way to explain how things behave or why they behave in certain way. It is different from other disciplines of inquiry since science demands evidence and the interpretations made are based on observations of natural phenomena. (P3, post-questionnaire)

> Science turned out to be a very interesting field. It is just more than simple data being collected and analyzed. Yes, I still believe that it's different from religion since it should be based on observations (even if in both sciences and religion there are many things that we can't be certain of or 100% sure). (P8, post-questionnaire)

Participants' belief in the tentativeness of scientific knowledge was also evident in their views of scientific theories and laws. Compared to 60% at the beginning of the study, only 17% of participants explicitly noted that scientific laws are "fixed" or "certain" in their post-instruction responses. A majority of participants (67%) noted that "both scientific theories and laws are subject to change" (P15, post-instruction questionnaire). Similarly, compared to 60% at the outset of the course, only 13% of the participants still indicated that scientists were "certain" or "100% sure" concerning the structure of the atom.

In this regard, about 53% of participants' post-instruction responses conveyed more informed views of the dynamic nature of scientific knowledge and the causes underlying changes in this body of knowledge. It is noteworthy that a majority of these latter participants noted that changes in scientific knowledge might be brought about by new ideas and theories, in addition to new evidence and improved technologies:

> Science is subject to change because it depends on observation of a phenomenon and creating theories and laws that are logical and consistent with the phenomenon under study. Theories change, therefore, because the ideas people come up with differ. (P30, post-questionnaire)

> In my opinion, scientific ideas are subject to change. With time new equipment appear and new theories develop which allows a new range of observations and experiments thus leading to the formulation of improved theories and new laws that may reject or enhance previously tested ones. (P11, post-questionnaire)

In this context it should be noted that a substantial portion of participants elucidated more informed views of the nature and function of scientific theories and laws, as well as of the relationship between them. Compared to almost none at the beginning of the study, about 43% of participants articulated more informed views of the inferential and well-substantiated nature of scientific theories at the conclusion of the course:

> A theory is an inferred explanation for patterns in observable phenomena. Also, the theory is backed up by a wide set of observations that scientists made of these phenomena. (P5, post-questionnaire)

> A theory is organized, logical and applicable in a relatively wide variety of circumstances. It is inferred; we can't observe it directly. However, it predicts or otherwise explains a lot of observations of the behavior of a given set of phenomena just like the kinetic molecular does with explaining the behavior of gases and the transfer of heat. (P17, post-questionnaire)

Moreover, many participants (36%) specifically referred to the explanatory and predictive functions of scientific theories as well as their role in directing future research:

> Scientific theories help us to understand how the world works. They help us analyze, predict and explain the nature of behavior of a given set of phenomena. They help us do more studies about the world by raising even more questions that need answers. (P19, post-questionnaire)

Compared to 76% at the beginning of the study, only 13% of participants explicated a hierarchical view of the relationship between theories and laws (the view that theories become laws if "proven") at the conclusion of the course. Sixty percent of all participants elucidated more adequate views of this relationship. These participants noted that theories and laws are different kinds of scientific knowledge that perform different functions:

> In science, a law is a statement that describes the relationships between aspects of phenomena. For example, Charles' law describes a relationship between the temperature and the volume of gases . . . While a theory is a reasonable explanation of observed events that are related. It helps the scientists in their researches. For example, gases are pictured as being made up of many small particles called molecules that are in constant motion: the kinetic molecular theory. (P1, post-questionnaire)

Additionally, favorable changes were evident in participants' views of the imaginative and creative NOS. In their pre-instruction responses, 17% of participants noted that scientists do not use imagination and creativity in their investigations. Also, 63% of participants either noted that scientists' use of creative and imaginative elements is limited to the planning and design stages of investigation or assigned to the terms imagination and creativity meanings other than the invention of explanation or theoretical models and entities to account for patterns in empirical evidence. By comparison, none of the participants noted that scientific investigations do not involve imagination and creativity at the conclusion of the study. Moreover, 67% of participants elucidated more adequate views of this NOS aspect as evident in the following representative quote:

> Scientists use their creativity and imagination during investigations. When something is not observable scientists must use their imagination. They have to invent hypothesis and theories to imagine how the world works and then how they could account for observations of reality. This is as creative as composing music. (P15, post-questionnaire)

Moreover, many participants (43%) demonstrated informed conceptions of the creative and imaginative NOS in their discussions of atomic structure. These participants noted that "the atom's structure is a model derived from inferences . . . Scientists used a lot of imagination and creativity to put this model together" (P30, post-questionnaire).

The Content-Boundness of NOS Understandings

As noted earlier, two items on the NOS questionnaire were content-specific. One item was related to content covered in the investigated course, namely atomic structure, and asked participants whether scientists were certain about the structure of the atom and the kind of evidence they believed scientists used to derive this structure. The other item was related to the dinosaur extinction controversy, which was not discussed in the course. This item presented the controversy and associated hypotheses and asked participants how was it possible for scientists to reach different conclusions regarding the cause of the extinction even though the have access to and use the same data.

Despite their seemingly different natures, the two items share significant similarities in terms of the NOS aspects they invoke. "Atoms" are inferred entities and the "extinction" is an inferred event. While "atoms" are far removed from scientists in terms of spatial dimensions, the "extinction" is far removed in terms of time. Both "atoms" and "the extinction" cannot be "seen" or directly observed and only indirect evidence could be used in answering questions related to them. Moreover, in both cases, the issues are similar in terms of adjudicating between alternative hypotheses and deciding what stands as a *valid* and *accurate* account of these aspects of our natural world given the empirical evidence available. As such, both items invoke understandings of the tentative, empirical, inferential, imaginative and creative, and theory-laden NOS among many others.

However, analyses of post-instruction responses indicated that participants were more successful in applying the NOS aspects addressed in the course in the context of discussing atomic structure as compared to dinosaur extinction. Only four participants (13%) explicated naïve views related to atomic structure at the conclusion of the study. They noted that scientists were certain about atomic structure because they are able to "see" atoms using powerful microscopes. The larger majority of participants (77%) elucidated more informed views of the tentative and inferential, though necessarily empirical, nature of the model of the atom and demonstrated an understanding of the distinction between observation and inference:

> Scientists are not 100% sure of the structure of atoms. The atom's model was inferred from observations collected from experiments such as Rutherford's experiment where he used a radioactive element that shot a beam on thin gold foil, then the result was shown on a zinc-sulfate screen. (P16, post-questionnaire)

> Scientists are not certain about the structure of the atom because they have never actually "seen" an atom or its internal structure. What scientists know about atoms are only inferences based on evidence collected from scientists'

> like Rutherford, Chadwick, Bohr, etc . . . Scientists used their imagination when they hypothesized how the atom works. Their use of data and observation may help them to reach a logical representation of the atom. (P17, post-questionnaire)

In marked contrast, participants' understandings of the above NOS aspects were not evident in their responses to the dinosaur extinction controversy. Favorable changes were evident in the case of a minority of participants. Compared to 20% at beginning of the study, 40% of participants expressed informed views of the inferential and theory-laden aspects of NOS as they grappled with trying to explain how is it possible for scientists to reach different conclusions as to the cause of the extinction based on the same set of evidence. The remaining 60% of participants expressed more naïve views. However, what is noteworthy is that these naïve views were different from those articulated at the beginning of the study.

As noted earlier, in their pre-instruction responses, 63% of participants attributed the controversy solely to the "lack of evidence" (33%) or the fact that "no one was there to know what killed the dinosaurs" (30%). These views were consistent with a simple dualistic "right/wrong" conception of how valid knowledge is generated. The implication being, 'No one knows what happened. Scientists need to get *all* the data to be able to decide what killed the dinosaurs.' Only a small minority of participants (16%) expressed similar views in their post-instruction responses. A substantial portion of participants (47%) now attributed the controversy to the fact that every scientist was entitled to their own point of view. Even though the basic notion of "No one knows what really happened" (P21, post-questionnaire) was still prominent, many participants now took this to mean, "We will never know what caused the extinction . . . So, each scientist can have his own view or opinion of what killed them [dinosaurs]" (P21, post-questionnaire):

> I believe that none of these scientists knows the answer . . . Not all scientists think in the same way, that is why, even though, they have access to the same

> information, they do not reach the same conclusion. Each derives his conclusion based on his own personal point of view concerning what happened. (P7, post-questionnaire)

> Scientists arrive at different conclusions for everyone sees only his own perspective of view. After all they can't know what killed the dinosaur and personally I think they will not arrive to the answer. (P14, post-questionnaire)

What is noteworthy in the above representative quotes is that, in contrast to their discussions of atomic structure, participants did not assign a central role for scientists' empirical observations and did not note that scientists' varying conclusions still need to be consistent with these observations. The few who commented on the role of evidence in the controversy, noted that scientists "play" with the evidence intentionally:

> The two groups of scientists used the same set of data but arrived to different conclusions . . . Because they have different points of views, that is how they turned out to have different conclusions. Scientists play with data, they want to prove that they are right and the other is wrong. (P30, post-questionnaire)

These latter views seemed to reflect a shift in some participants' conceptions from a "scientistic" to a "naïve relativistic" worldview. This lead to further examination of the data where other similar references to a "relativistic" conception of science, such as the ideas conveyed in the following quote, were found:

> Scientists are not certain of the shape of the atom. The choice of its representation is arbitrary and there is no specific evidence for it. (P18, post-questionnaire)

Evidence to support this tentative hypothesis was sought during the post-instruction interviews that were conducted with six randomly selected participants. In addition to clarifying their responses to the post-instruction questionnaire, the interviews aimed to probe these participants' worldviews in more depth.

Intolerance for Ambiguity: The Shift toward "Naïve Relativism"

Analyses of responses to follow-up and probing questions during post-instruction interviews substantiated the aforementioned hypothesis concerning a possible shift in some participants' conceptions toward a "naïve relativistic" view of science. Such a shift was most likely a reaction from participants to the realization that science is not absolute and does not provide definite answers. Participants were asked how they felt about the fact that scientific knowledge, though durable, is tentative or that science was inhabited by a host of unobservable entities such as atoms and black holes. Four of the six interviewees indicated that they felt "confused," and as one interviewee put it, "used:"

> P14: I used to think that science is something stable, fixed and it doesn't change. But if you really look into it, many things in it change. It is not fixed. Many things change. So I don't know to what limit we can say that science is stable the way I learned it and the way I am supposed to teach it to kids. I mean we say that science is definite. This way we get that answer and this way we get that answer.
> R: How does it make you feel?
> P14: Used.
> R: Can you explain some more?
> P14: You don't want to learn about something and then within a short period relative to your life learn the opposite. It is kind of confusing, it contradicts what you learned before.

> R: Does it bother you that there are concepts in science that are not concrete or observable like black holes and atoms?
> P23: . . . I had this concept that science should be always concrete, but since it is not always so, it is not so reliable, then maybe we should doubt everything that other people give us that is scientific. And we should not say that science is laws and rules because they simply could be wrong.

Interviewees expressed an intolerance for ambiguity. They were not comfortable with the notion that many ideas in science were not "proven" or "certain." For the interviewees, having several possible answers was confusing, especially when it is not possible to know the "correct" answer by "checking things out to see what happened:"

> I don't feel conformable about this [dinosaur controversy] because you read this whole paper saying one thing and another saying another. So, they have to make up their minds. And you get more lost because maybe you read one thing and you find it logical and then you read another and you find it logical too. You usually don't know what is going on. You cannot go back in time and check! (P11, post-interview)

Moreover, even though these participants realized that scientists could be "subjective" in the sense that their theoretical commitments, backgrounds, and training could influence their interpretations and explanations of data, they "wished" that scientists could be "objective:"

> R: So, what is the role of evidence?
> P30: Well, scientists collect evidence to find out, let us say about the dinosaurs. They don't just come up with things from the air, they base it on evidence. Their ideas can be different, like dinosaurs . . . They come up with different reasons [for the extinction] but they are all based on data. But evidence can be also taken subjectively. So, we cannot totally rely on science.
> R: Tell me more about this.
> P30: For example, if you have something in mind, always the person whatever he wants to find, he will look for. He will be blind to something else. And even when experimenting, the fact that he is looking for something, will make him look for it. That is, he will concentrate on certain things to find out, to get what he wants.
> R: Even a scientist?
> P30: I think that some do.
> R: Does this bother you?
> P30: Yes, but you cannot do anything about it. But it bothers me because when they have to explain things to us they won't do it objectively and they know they are scientists and they should be objective about their ideas.
> R: But you said before that they cannot be totally objective because they are human?
> P30: Yes, but I don't know I hope it can be done.
> R: How does it make you feel?
> P30: I think it makes feel confused because I don't have anything to rely on fully. But I don't blame them for it. I wish that they could be more objective so that I would feel more at ease.

As such, in the face of the "lack of certainty," these participants seem to have adopted a relativistic position. Moreover, their lack of "faith" in science seems to have generalized.

Following discussions of the dinosaur extinction controversy in which interviewees expressed concerns about scientists' biases and personal opinions and how these might impact scientists' conclusions, interviewees were presented with a hypothetical scenario. Interviewees were told that the government was planning to construct a nuclear reactor in the outskirts of the city where they lived. Backed-up by the support of a large number of scientists, the project director presented evidence that the reactor is a safe and environmentally "clean" alternative to traditional means of generating electrical power. However, some human rights and environmental activities presented evidence provided by some scientists that discredited these assertions. As such, the government decided to poll the public before taking any decisions regarding the construction of the reactor. Interviewees were asked, "What would you vote for and why?"

Given a situation where the stakes were high, none of the interviewees chose to put her faith in the larger group of scientists who asserted that the reactor was safe. Initially, all six interviewees tried to ascertain whether the reactor will be 100% safe. When they were told that making this assertion was not possible given that a few scientists did not believe that such levels of safety could be guaranteed with a nuclear reactor, all six participants voted against constructing the reactor:

> P11: I would definitely not construct the reactor.
> R: Why?
> P11: Because it has at least 1% danger. I will keep on testing it several times till I am sure that it is safe.
> R: But how will you know that you will get a "sure" answer?
> P11: I don't know, I will continue trying till I get there and if I don't . . . Well, that's the problem, that's what is bothering me. We can't have definite answers in science. All those scientists could just be wrong and we could have a disaster.

> P23: I wouldn't do it, I wouldn't take the risk.
> R: But a large group of scientists are saying that the reactor is safe. Only a few are saying it is dangerous!

> P23: Just the fact that some are saying that it is dangerous even though it is just an idea makes me consider it, so I wouldn't do it. I would rather come up with something that is definitely not dangerous. Although nothing is definite or 100% sure. I don't know, I just won't do it.

In as far as the six randomly selected interviewees were representative of the 30 participants, a majority of the preservice elementary teachers enrolled in the investigated course seemed to be unable to handle the ambiguity that comes along with viewing scientific knowledge as a product of scientists' inferences and creativity in their attempts to make sense of their observations of natural phenomena, rather than as a reservoir of "facts" about the world uncovered by scientists in an objective search for the "truth." The apparent result for many of these participants was a shift from "believing" in science to viewing scientific knowledge as 'someone's opinion about what is going on.'

Discussion and Implications

Consistent with research on science teachers' views of NOS (e.g., Aguirere et al., 1990; Bloom, 1989; Carey & Stauss, 1968, 1970; King, 1991), participant preservice elementary teachers held naïve views of many aspects of NOS at the beginning of the study. What is noteworthy about the present results was that, unlike our previous research participants whose NOS views lacked an overarching framework (e.g., Dickinson et al., in press; Dickinson & Abd-El-Khalick, 2000), the views of a substantial portion of this study's participants were consistent with, and organized around a "scientistic" worldview. Several substantial and favorable changes in participants' conceptions of the six target NOS aspects were evident at the conclusion of the investigated course. These results substantiate our claim regarding the effectiveness of an explicit reflective approach in enhancing prospective teachers' NOS views (Abd-El-Khalick & Lederman, 1998).

Moreover, the study indicates that the context and content in which preservice teachers learn about NOS influence their ability to apply their understandings to novel contexts and content. In the present study, participants were largely more successful in elucidating their acquired NOS understandings in the context of issues related to "familiar content" (atomic structure that was covered in the course) as compared to "less familiar" content (dinosaur extinction). This was the case even though the issues raised in relation to the two content areas invoked similar aspects of NOS. This finding corroborates and helps to explain why participant preservice secondary science teachers in our previous research (Abd-El-Khalick et al., 1998; Bell et al., in press) often complained that NOS instruction and activities they experienced in their science methods courses were not helpful to them in addressing NOS instructionally during student teaching in the context of science content that was different from that explored in the methods courses. As such, the tentative claim could be made that learning about NOS in the context of science content courses, as opposed to science methods courses, may facilitate the translation of teachers' NOS views into instructional practice. This claim needs further examination and validation.

This latter finding, however, raises some serious concerns regarding the potential success of the attempts undertaken to help science teachers address NOS in their teaching. The lack of transfer of learning between varying contexts is too well known to be reiterated here (see Gage & Berliner, 1992). However, providing prospective teachers during their limited residencies in teacher preparation programs with experiences that guarantee one-to-one correspondence with what they are expected to achieve in terms of NOS instructional outcomes in their schools should prove to be a very difficult feat. More research into the transferability of NOS understandings between various science content areas is in order.

Additionally, the finding that many participants seemed to have abandoned a "scientistic" worldview only to adopt a "naïve relativistic" one is consistent with findings of studies that investigated the development of college students' epistemological views (e.g., Belenky, Clinchy, Goldberger, & Tarule, 1986; Perry, 1970, 1981). In these studies, only a handful of senior students and some graduate students adopted the more fruitful "committed" view of relativism (Perry, 1970). The majority of college students experienced difficulties coming to terms with the tension between the tentative nature of scientific claims and the notion that some of these claims are "more valid" or "credible" than others. Many participants in the present study were not able to internalize the notion that even though there are no "definite" answers in science, scientists are still able to adjudicate between conflicting claims about the natural world and assigning higher levels of validity and accuracy to some claims and less to others. Rather, faced with the uncertainty of science and lacking tolerance for ambiguity, many participants simply adopted an "anything goes" position whereby every scientist, like any other person, is entitled to his/her own view of the phenomena in question.

This finding raises questions regarding the interaction between learners' epistemic worldviews and their learning about specific NOS aspects, and concerns regarding the developmental appropriateness of those NOS aspects that we desire K–12 students and their teachers to internalize (e.g., AAAS, 1993; NRC, 1996). In our own work (e.g., Abd-El-Khalick et al., 1998; Dickinson et al, in press) we have argued that controversial aspects of NOS, such as the existence of one objective reality or multiple phenomenal realities, should not be of concern when addressing NOS in the context of K–12 education. Rather, the focus should be helping teachers and their students internalize conceptions of specific non-controversial aspects of NOS, such as that scientific knowledge is tentative and partly inferential. We have also argued that the well-documented learners' difficulties in internalizing more informed views of NOS were instances related to difficulties associated with conceptual change. While this is still very plausible, it might not account for the whole story.

The results of the present study indicate that learning about specific NOS aspects might interact with learners' broader epistemic views in ways that might hinder such learning. Moreover, issues regarding the developmental appropriateness of NOS conceptions need to be taken into consideration. Consistent with empirical research, participant elementary teachers were at a stage where they were more likely to adopt a "naïve relativistic" as compared to more committed forms of relativism (Belenky et al., 1986; Perry, 1981). For many of these participants, NOS instruction seems to have facilitated or expedited the shift from "dualism" or "scientism" to "naïve relativism." It follows that those interested in teaching about NOS should attempt to research and understand the interaction between learners' broader epistemic views and their learning about specific target NOS aspects. Moreover, in addition to considering the well-documented difficulties related to changing learner's alternative conceptions of NOS, these researchers should also investigate the developmental appropriateness of these NOS aspects.

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PROJECT T.E.A.M.S. (TEACHER EDUCATION AT AKRON FOR MATHEMATICS AND SCIENCE)

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Needs

While primarily focused on mathematics and science achievement of students in K-12 schools, the current state and national standards mandate excellent preservice teacher preparation programs as well as continuous inservice teacher enhancement efforts. Before such courses can be effectively implemented, a shared understanding of state and national standards, inquiry methodologies, cooperative learning techniques, access and equity, authentic assessment must be arrived at by all educators involved in teacher preparation. These educators include faculty at The University of Akron (UA) in the College of Arts and Sciences, in the College of Engineering, and in the College of Education.

At The University of Akron, faculty members both within and across colleges are engaging in dialogue concerning the quality of university teaching as part of the Carnegie Teaching Academy Teaching Program. But a sustained conversation about excellent teaching is not enough. Such conversations set the stage for team planning and teaching of courses within the programs whose responsibility for implementation is shared by more than one college. What is needed is a focused, coherent, coordinated, and collaborative effort on the part of all faculty involved in teacher preparation of those who will teach the early childhood and middle level students of the twenty-first century.

Other voices to add to the conversation include those of inservice elementary, middle, and secondary school teachers of mathematics and science. Collaboration with these teachers whose knowledge of pedagogy, experience working with children, and curriculum development skills will benefit those university faculty members developing and delivering teacher preparation courses.

The University of Akron is fortunate to be located in close proximity to other institutions of higher learning involved in teacher preparation, urban and suburban school districts committed to high academic standards for mathematics and science education, and to a newly-formed urban professional development center. Too often, however, these entities operate along parallel paths and seldom come together for meaningful conversation or exchange. What is needed are planned opportunities for all groups committed to educational excellence in mathematics and science for all children to express their vision and to listen to their common voices.

Over the past several years, grant-funded projects have facilitated inservice teacher training programs in inquiry-based instruction in mathematics and science. What is still needed by many inservice teachers of mathematics and science, however, are workshops to improve their science and mathematics content knowledge. In addition to the content issues, an emphasis on issues of equity and of access to science and mathematics study by members of underrepresented groups is needed. UA faculty are well-qualified to conduct content-update workshops and are committed to increasing the number of underrepresented people in mathematics and science. Educators in the Akron/Summit county area can teach UA faculty much about the current status of mathematics and science education in the local community.

Goals

The principal goals of Project T.E.A.M.S.are:

1. To strengthen communication and coordination among college faculties to improve the teaching and learning of mathematics and science throughout preservice teacher education programs at The University of Akron.
2. To implement inquiry approaches to teaching mathematics and science, particularly at The University of Akron, in the content courses that fulfill part of the requirements for early childhood and middle level licensure in Ohio.

3. To establish an ongoing collaborative dialogue among institutions of higher education, local school districts, and professional development centers in the region around The University of Akron.

4. To improve mathematics and science education for students in underrepresented groups while, concurrently, improving the mathematics and science knowledge base of local inservice teachers.

Design

Actions and Evaluations

Project T.E.A.M.S. involves faculty from the College of Arts and Sciences (Department of Mathematics and Computer Science, Department of Statistics, Department of Chemistry, Department of Physics, Department of Biology, Department of Geology), the College of Engineering, and the College of Education (Department of Curricular and Instructional Studies). Faculty in these departments currently teach courses in the present and future programs for students seeking early childhood and middle level licensure in Ohio. Four actions involve faculty from the aforementioned departments.

Action One

Project directors invited the deans of the Colleges of Arts and Sciences, Engineering, and Education, the Chairs of the Departments in these colleges, and their respective faculty to participate in a series of four lunch time "brown bag" programs. The focus of these "brown bags" was the presentation and discussion of trends and issues of mathematics, engineering, and science education. Discussion facilitators assisted the participants to raise questions about mathematics/science education and the role of mathematics/science domain educators in the preparation of all preservice teachers. Topics for the programs addressed implications to instruction from the results of the Third International Mathematics and Science Study (TIMSS); assessment of mathematics and science learning; national and state standards for mathematics and science teaching and learning; and philosophical underpinnings of mathematics and science education.

Evaluation

Participants were asked to submit questions/concerns related to the topic addressed by the program, about teaching science and mathematics from an inquiry mode, and/or about current issues in science and mathematics education. These questions/concerns informed the direction of the project, especially the pedagogical methodologies for the Action Two chautauqua.

Action Two

A regional three-day "chautauqua", held at the Goodyear Center for Learning, included faculty members from universities in the NE Ohio region along with UA faculty members. The facilities and meals were graciously donated by the Goodyear Tire and Rubber Co. The chautauqua explored the epistemology underpinning inquiry, but more importantly, in the chautauqua, participants engaged in conversations about mathematics and science teaching and learning. Participants were asked to come away from this seminar with their own personal action plan for implementing inquiry-based practices in the course(s) they teach.

Participants studied in-depth the topics explored briefly in the "brown bag" lunches. Topics presented include: TIMSS study group findings; inquiry lessons; and national and state standards for mathematics and science. In addition, reflection, conversation, and inquiry were a vital part of the chautauqua. In the keynote address, Dr. Virginia Anderson, professor of biology at Towson University and project *Reciprocal Science Success* director, connected middle level learning to teacher preparation and preservice mathematics/science domain learning. Dr. Anderson also addressed issues of assessment of inquiry and learning in undergraduate courses.

Evaluation

At the close of the chautauqua, participants were asked to answer these questions: When I began the chautauqua, where did I see myself on the issues of inquiry-based instruction? Where do I see myself now? or When I started the chautauqua, I felt ___? and What is my personal action plan for implementing inquiry-based instruction? The project directors copied participants' journals and read the entries to discover emergent and unfolding themes and patterns, noting how participants planned to apply their learning.

Action Three

Throughout the summer of 1999, Project T.E.A.M.S. faculty members developed or modified mathematics and science courses to include inquiry pedagogy. Courses in mathematics and environmental science were developed; courses in physics, astronomy, and statistics were modified. Secondly, this Action required the development of curriculum and instructional materials to include specific modules, units, and/or activities for the aforementioned courses.

Evaluation

Several UA participants produced curriculum proposals for new or modified courses. Two such courses have been approved for adoption. Project directors performed an internal review of each course to ascertain the application of national and state standards, the applicability to preservice teacher education standards, the appropriateness and relevancy of content, and the inclusion of inquiry-based pedagogy.

Action Four

Action Four focuses on the content knowledge of inservice science and mathematics teachers. Content-focused workshops, delivered by Project T.E.A.M.S. faculty throughout the 1999-2000 school year, will enhance the mathematics and science knowledge base of local inservice teachers. In addition to the content issues focused on in these workshops, emphasis will be placed on issues of equity and of access to science and mathematics study by members of underrepresented groups. These content-focused workshops will be forums where Project T.E.A.M.S. modules, units, and/or activities designed by Project T.E.A.M.S. faculty members for the inquiry-based content courses will be field-tested.

Evaluation

UA instructors will administer pre- and post- content assessment instruments. Project directors will ask the UA instructors questions from the Pathwise program. These include:

1. What are your goals for student learning for this lesson? Why have you chosen these goals?
2. To what extent did students learn what you intended? How do you know that?
3. In what ways were your teaching methods effective? How do you know that?

4. How and when do you plan to evaluate student learning on the content of this lesson? Why have you chosen this approach to evaluation?

5. How will you use this information from the evaluation to plan future instruction?

6. How will the evaluation guide the assessment of the teaching?

Answers to these questions will form the basis of the evaluation of Action Four.

SCIENCE TEACHER BELIEFS: TOWARD AN UNDERSTANING OF STATE SCIENCE EXAMS AND THEIR INFLUENCE ON TEACHER BELIEFS

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> "*Because of the uneven, and sometimes very low standards in the present [teacher certification] system, teachers are often not trusted to use their own judgement as are other professionals. They are often told what to do and exactly how to do it. They are watched and evaluated MORE like hired hands in old-fashioned factories than respected professionals who are counted on to use their own judgement because they have met high standards.*"
>
> Albert Shanker, 1986

Beliefs Toward The Regents System: An Overview

Over two years of student-teacher observations led to the preliminary development of the anonymous survey used in this study. As formal and informal observations of student-teachers were made in Regents science classrooms, aspects of these pre-professionals' thinking and their subsequent overt teaching practices might cause concern for those involved with science education reform initiatives. Many student teachers seemed to have one over-arching or main concern that did not seem congruent with reform in science education. The following statement summarizes the very core of this study and expresses a primary goal of Regents science teachers: *"I have to* [or will have to, in the case of student teachers] *get these kids ready for the Regents!"* This belief, indeed a reality, in the minds of student-teachers seemed to prevent all but one observed student teacher (out of approximately 18) in two years from taking risks by trying different teaching approaches.

In some instances, methods suggested by the science educator/college supervisor (first author) would come in direct conflict with the methods suggested by the cooperating teacher. The usual problem was that the suggested method "would use up valuable time and not enough [Regents] content could be covered." Even as the suggested methods were entirely research-based (inquiry, nature of science, cooperative learning, etc.), they were sometimes met with considerable resistance.

Student-teacher beliefs came to the forefront during each subsequent student-teaching seminar. That is, if these student teachers of science were in Regents science classrooms, they shared their primary concern openly; the "coverage of material" issue. In many cases, a student teacher's sole motivator for a given lesson was a statement such as "this is going to be on the regents!" And, this statement was sometimes said in a slightly threatening manner to the students or to give a sense of warning. While student- teacher observations numbered fewer than 20, the rate at which these statements were made was of concern to the college supervisor.

As a result of observations and discussions with Regents science teachers and student teachers, this Teachers-of-Regents-Beliefs Survey was developed to determine how Regents science teachers' beliefs might be linked to what the literature reports as *effective methods of science instruction*. For instance, effective instructional methods such as inquiry and cooperative learning that model the way science really happens (NRC, 1996).

This study follows the work of Tillotson (1998) who described the impact of state-mandated science curriculum on teacher beliefs in New York. Tillotson's qualitative report indicated that teachers "unanimously agreed" that the New York State Regents system influenced:

1. their curriculum decisions,
2. assessment strategies, and
3. the considerable time spent on practicing to take the exam.

Perhaps most importantly was the impact of the regents system on beginning teachers who were pressured to find ways of covering all the "required content." Pajares's (1992) work on teacher beliefs suggests that educational research should focus on teacher beliefs as central to any inquiry. Finally, many have reported on the influences of belief or belief patterns and their direct impact on the actions taken by teachers in their classrooms (Wahlstrom, et.al. 1978; Czerniak, 1998; and Fang, 1996).

Survey Methods

The survey used in this study was originally developed in the spring of 1999. The population of Regents science teachers was selected from a randomly stratified pool using the Directory of Public Schools and Administrators of New York State. Science teachers in school districts from non-adjoining counties were selected as potential participants. This method provided teachers from varied geographical and demographic settings across the entire state. In addition to the countywide selection of Regents science teachers, five large urban centers were also sent surveys in a mass mailing. Thirty surveys were sent with each of these mailings. Since part of the survey requested demographics of teachers in urban settings, larger cities were purposefully selected.

At least three surveys each were mailed to "Regents Science Teachers" in all other targeted school district. The hope was that the anonymous surveys would eventually be given to the appropriate science departments. The surveys could be copied and distributed among the Regents science faculty. From more than 1,400 surveys sent a total of 419 were returned, making the return rate on this survey approximately 30%.

The fourteen-item surveys were returned to the first author over a period of almost three months, from May through July 1999. The four-choice survey provided the options of Strongly

Agree, Agree, Disagree, and Strongly Disagree- in that order. These choices were later assigned numbers from 1 to 4, which made preliminary statistics possible. The demographics used included:

____ Subject(s) taught,

____ Years Teaching Regents,

____ Scheduling type of Block or Periods,

____ Type of School: Urban, Suburban, Rural, Public, or Private

In this study, the researchers were interested in observing differences in teachers' beliefs and attitudes as a function of the demographic information listed above. Chi-square tests of association were run to determine any significant differences that may have existed. In addition to the quantitative data, there was opportunity for each teacher to provide written comment about any question. With this option, the teacher was able to detail their feelings, beliefs, or attitudes about each question in a narrative form.

Findings And Discussion

Results discussed in this study do not make claims to a larger population due to the limitations placed on this survey. However, one thing seems apparent from the data gathered from this survey: the beliefs of Regents science teachers range widely when the various demographics are considered. There is, however, no way to tell with this survey as to the various reasons that teachers may have responded the way they did. The hope was that teacher's written comments would shed more light on the rationale behind their responses.

For the purposes of this paper, only the most significant trends in teacher beliefs are reported. In the section that follows, the relationships between three broad ranges of *years teaching a Regents course* and items on the survey are expressed in tables with discussion immediately following. The Teachers-of-Regents-Beliefs survey asked teachers to state the number of years they had been teaching their Regents course. As was expected, the years teaching ranged from one year teaching experience to more than thirty years. The three ranges chosen for comparison included: 1 to 5 years, 6 to 20 years, and more than 21 years. Rationale for the first range (1 to 5 years) was "the years that most teaching habits would most likely form". The rationale for the second range (6 to 20 years) was "years that confidence would most likely grow and risks in changing teaching strategies might be taken". The rationale for the third experience range (more than 21 years) included "those teachers who had the most opportunities for professional growth and may have seen the majority of reform movements within their careers." As a result, they may have developed key or essential teaching strategies they felt were most effective for their students to do well in their Regents science courses.

Survey Results

Tables 1 through 8 illustrate the relationships between the years experience ranges and how teachers in each range responded to the questions on the survey. Questions 1, 3, 9, 10, 12, and 14 were not used in this report because of confusion as reported by teachers or the questions were found not applicable to all ranges of years teaching experience. While many tables might be generated here to compare the variability of responses between populations, only those comparisons that demonstrated a statistical significance with chi-square tests at the .05 level or those that were thought to generate interest to the science education community based on their overall means are reported.

Finally, There are assumptions made with each survey question. While the questions themselves arose from two years of student and classroom teacher observations and interviews, the content of each question was intended to present issues of teaching that can be found in the research literature. These issues would either be accepted as effective teaching strategies or as philosophical cannons in the science education community. For example, it is assumed that creative teachers are more effective in their science classrooms. This assumption relates directly to question seven: *My Regents course permits me to be a creative teacher.* Similarly in question number eleven: *There is no tension between what I know as effective science teaching and the teaching methods I must employ in my course.* The term "tensions" is used to relate to issues of job security that occur as a result of the act of teaching. Again, it is assumed that tensions are negative and, as a result, have an adverse effect on teaching. Similar rationales were used in the framing of each question on the survey. Table 1 shows that *Regents teachers believe they are teaching for real-world science understanding* as one of their goals in their Regents course.

Question 2. "One of the primary goals of my course is for most of my students to apply concepts in a "real-world" context."

Table 1

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	36	59	7	2	104
6 to 20 years	55	87	23	9	174
>21 years	43	56	8	1	108
Totals	134	202	38	12	386
%	35%	52%	10%	3%	

Question 4. "The Regents science exam is an appropriate summative assessment for my course."

Table 2

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	8	28	48	20	104
6 to 20 years	15	41	87	32	175
>21 years	13	17	49	27	106
Totals	36	86	184	79	385
%	10%	22%	48%	20%	

Table 2 shows teacher belief patterns toward the Regents exam as a summative assessment for their course. A majority of teachers gave alternative assessments as being more appropriate and these are discussed in a later section. The data indicate that 68% of respondents in this study **disagree** with the current summative Regents exam system as an appropriate summative assessment for their course. The mean for all responses was 2.77.

Question 5. "The scope of my curriculum would be very similar if no Regents exam existed."

Table 3

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	11	35	40	18	104
6 to 20 years	27	58	64	27	176
>21 years	11	20	40	37	108
Totals	49	113	144	82	388
%	13%	29%	37%	21%	

Regents teachers were asked *if the scope of their curriculum would be similar if no Regents exam existed.* A chi-square test of association yielded a p-value of .003, indicating a relationship exists between years of experience and beliefs concerning this question. Table 3 data shows that larger numbers of teachers with more than 21 years of experience believe that they would have a different scope to their course if no Regents exam existed. And, while teachers responded both positively and negatively toward this question, a majority disagreed. It is logical that teachers with more experience would be more inclined to change the scope of their course after they have gained the necessary practical experience in their respective systems. It is also logical that teachers with less experience might be less likely to change.

Question 6. "The sequence of my curriculum would be very similar if no Regents exam existed."

Table 4

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	10	24	49	21	104
6 to 20 years	21	47	81	25	174
>21 years	8	17	44	37	106
Totals	39	88	174	83	384
%	10%	23%	45%	22%	

In what order would teachers place the content of their courses if they had no Regents exam? A significant chi-square test with p-value of .006 indicates a relationship between years of experience and beliefs concerning the sequencing of science topics in the curriculum. As seems to be the case in Table 3, Table 4 shows that science teachers with more years experience are likely to *disagree with keeping the sequence of their courses the same* if no Regents exam existed. That is, they would be likely to change the order of the science content.

Question 7. "My Regents course permits me to be a creative teacher."

Table 5

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	21	41	32	10	104
6 to 20 years	33	73	59	10	175
>21 years	19	29	44	15	106
Totals	73	143	135	35	385
%	19%	37%	35%	9%	

Table 5 demonstrates the responses to the question that details the beliefs surrounding the amount of *creativity* teachers feel they are able to exhibit as a teacher in a Regents course. Forty-four percent of Regents teachers disagreed they could be a creative teacher as a result of their course. A related comment was given by a Regents Physics teacher with 32 years experience:

> I personally have sacrificed activities that I know from student feedback to be powerful for students for the sake of time to cover topics which might appear on the exam. I believe that we went from being creative, focused and excited to feeling unappreciated, depressed, and rudderless with abdication. Being treated as professionals is empowering. Not being trusted to create appropriate curriculum is debilitating. What we created required us to work longer and harder than now. Isn't it interesting that I hear more expression of tiredness, complaint, and burnout now that our "job" is easier?

Question 8. "Preparing students for the Regents exam is professionally rewarding for me."

Table 6

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	15	34	38	14	101
6 to 20 years	19	80	52	18	169
>21 years	17	22	52	16	107
Totals	51	136	142	48	377
%	13%	36%	38%	13%	

Overall, Regents teachers in the State of New York seem to be almost evenly split with their beliefs toward the Regents course being professionally rewarding. While almost exactly 50% of the regent science teachers who responded feel they are professionally rewarded by their course, the remaining 50% disagreed with the same item. A chi-square test for data regarding question 8 yielded a p-value of .002. The data indicate that science teachers in the 6 to 20 year range and those in the 21 and over range had different beliefs concerning the rewards of teaching regents. In a future study using focus groups of Regents science teachers may be able to shed more light on why there is such a polarization of thought on the issue of a *professionally rewarding class*. Or, why might a Regents science class be rewarding for some and not others?

Question 11. "There is no tension between what I know as effective science teaching and the teaching methods I must employ in my course."

Table 7

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	17	41	33	12	103
6 to 20 years	23	79	61	12	175
>21 years	13	44	36	15	108
Totals	53	164	130	39	386
%	14%	42%	34%	10%	

Data for Question 11 shows that 44% of New York State science teachers believe that tension does exists between what they know as *effective teaching methods* and what they must employ in their course. With these kinds of beliefs, what is the potential impact on instruction? In these days of increased science education reform, it seems unlikely that those who feel tension in their classroom will be likely candidates for accepting reform movements, even if they are in favor of reform movements.

Question 13. "I often use a phrase like "This is going to be on the Regents..." as a motivator for students."

Table 8

Teaching Experience	1 Strongly Agree	2 Agree	3 Disagree	4 Strongly Disagree	Totals
1 to 5 years	1	15	52	36	104
6 to 20 years	6	27	89	51	173
>21 years	5	20	55	28	108
Totals	12	62	196	115	385
%	3%	16%	51%	30%	

Observations of student teachers in Regents classrooms over a two-year period and discussions in student teaching seminars led to a question dealing with an often-heard phrase such as, "*This is going to be on the Regents*," or, "I've seen this on the Regents before." While these phrases varied in form, the tenor of the phrases indicated that any material covered in class was necessary because it would be on the Regents exam and the phrase was used as a motivator for learning the material at hand. As a result, Regents teachers were asked if they often used such phrases. Table 8. shows a strong indication (81%) that teachers believe they do not use such phrases frequently.

Regent Science Teacher Written Comments

Regents science teachers were also asked to provide written comments about their beliefs surrounding each survey item. They were free to state anything they wished about the question. These comments eventually led to the elimination of a few questions because of ambiguity or lack of applicability. While some questions were discarded for statistical analysis, discussion of teacher comments is presented here to provide the reader a window into their thinking.

As with the quantitative data, teachers varied widely in their opinions regarding the most appropriate assessments for their course. Suggestions ranged from "Keep [the Regents] as is" to "project/portfolio-based final assessments" as alternatives. Table 9 lists a summary of Regents science teacher-suggested final assessments. While some teachers offered more than one suggestion, most suggested one main idea such as portfolio, projects, or "make no changes at all!" And, while 26 Regents teachers considered the current final assessment appropriate as evidenced by their comments, a majority of those making comments suggested alternative assessments for their science students.

Teachers were asked this question at the end of the survey:

"What would you suggest as a summative assessment to show the quality
of science learning students are getting from your Regents course?"

Table 9

Projects	35
Lab Practical [application component]	30
"Keep the same Regents test"	26
Local Exams [teacher created]	23
Problem Solving Questions [open-ended]	20
Portfolios [of labs]	17
Essays or expressing in writing	15
Lab Journals	5
Oral Interviews or presentations	7
National competency exam	2
Total Teacher Comments:	180

While some would argue that a few of these suggestions might be merged, they are listed here to demonstrate the diversity of what teachers were thinking. The major themes that emerged with the last, open-ended survey item were that teachers thought a final assessment should:

- Put in less "petty" facts
- Go more in-depth on a fewer number of concepts,
- Provide more real inquiry,
- Have more real science

In the following section, teacher comments are provided so the reader may have a degree of indirect communication with the science teachers who responded to this survey. The quantity of comments listed here (both pro and con toward the Regents assessment system) are those actually stated by Regents Science teachers of New York State. Science teachers who commented positively toward this standardized assessment were much fewer in number.

Conversely, those science teachers who provided responses that were negative toward the assessment had more to say. Each quote came from a different science teacher.

Negative Views Toward the Current State Regents Science Assessments

"We have used a locally developed biology variance exam for the past 4 years as our Regents final. This is not only the best alternative, but is the only summative assessment that allows Biology to be learned by students in individual, relevant, or authentic ways. A Biology course, teacher, or curriculum should not be limited, influenced disproportionately, or judged entirely upon a 3-hour block of time in June. The Regents exam is standardized, valid, and some would say rigorous. Those are its good points. The exam is restrictive, biased, laden with *factoids*, vocabulary traps, and trivia. Those are some of its bad points. All educators would agree that there are better ways of assessing students in Biology. Not all educators are in agreement as to what that assessment should be. This is why we need to be given the autonomy of professional responsibility to develop local, state approved final exams."

"Fast pace of the course tends to turn a high percentage of the students from the subject."

"43 major topics in 40 weeks? Do the math!"

"Many students aren't ready for Regents work and many will never be. We are depriving many children of a meaningful education."

"Too broad a curriculum, very little mastery of anything."

"New state mandated assessments will hurt everyone, especially those not pursuing an academic program."

"Making "local" students take the current Regents is pathetic. You do not meet their needs."

"90 Multiple choice questions only benefit kids who are decent, exceptional readers. [Those] who know the concepts, but can't understand the basic vocabulary are severely penalized."

"The Regents exam is a "one-size-fits-all" test. We say that all children can learn and that each child learns differently, yet we give each child the same test of 94 multiple choice questions. The exam is as much a reading and test skills exam as it is a biology test. Overall the test is inconsistent with my teaching philosophy. A suggestion that I've made is to lengthen the time to complete the course and to give test modules rather than one test at the completion of the course. We want "hands on" science courses yet the State Education Department only requires 1200 minutes of laboratory work? (equal to 30, 40-minute periods). The S.E.D. keeps adding content to the course (see 1987) yet they profess "depth over breadth". What opportunity is there for children with other learning styles to demonstrate ability or learning?"

"1). Regents courses are encouraging students to memorize many unnecessary concepts. 2). the question on the Regents exams does not allow for enough student expression. 3). Students are discouraged by Regents, generally. 4) The Regents does not allow teachers to be as innovative and creative in their classroom as they would like."

"Regents exams insinuate a lack of confidence in teachers and their ability to assess their students."

Positive views toward the current state Regents Science assessments:

"The Regents exam is a powerful tool. It increases accountability for science teachers across the state. It is a valid benchmark for the amount of learning a New York State Regents science student has done. It sets New York State apart for excellence among the other states. Unfortunately the exam has become increasingly watered down over the past 15 years."

"The New York State [science] syllabus presents an excellent survey course. The exam ascertains consistency in presentation of this material. It keeps tabs on instruction.

Within the classroom, we have time to do additional research, projects, Olympics of the mind activities, etc. Lower level "Regents prep" classes are not taught Electromagnetic Applications or Optics. This breaks my heart, but the presentation must be slower, more demo/ lab oriented and this slows me down. I would personally choose to teach optics to a slower, less academic kid, but their regents exam results will be better if I teach the Atomic unit instead. I am evaluated (unofficially) based on my test scores."

"I think the present exam is a very effective evaluation tool. The problem is not the evaluation tool, it is the level of effort expended by the student. Our society does not truly value higher service. American students fail to do well not because of the method of instruction, the dollars expended, or the means by which they are increased. They fail to succeed because they do not care and do not try. What some people are looking for is a magic bullet that will result in learning without effort. Or, perhaps, if we alter the emphasis maybe it will seem that we are succeeding where before we failed; and only the parameter will have changed. No, the current syllabus and exam are fine. And, that is because there is no magic bullet. Only hard work yields results."

"A New York State "Regents Diploma" enjoyed its well-earned reputation because of its easily recognized value. By decreasing the number of externally imposed Regents exams needed to earn a "new" Regents diploma, that value is being degraded. It is no wonder that competitive schools are now turning to other standardized assessments like the AP exams to document their students' level of achievement. The effort to replace externally imposed standardized exams with alternative forms of assessment invites administration to manipulate the outcomes. Long experience with [a large] City School District has convinced me that corruption and fraud are the inevitable outcomes of putting the power to produce and evaluate "locally derived" "alternative assessments" into the hands of educational bureaucrats. Standardized exams are fair by definition and their use should be expanded, not curtailed. The creativity is in the teaching and learning. If an alternative program is superior, it will show up on the exam."

Implications

Results of this preliminary survey indicate a wide range of belief patterns among Regents science teachers in the state of New York. Those strongly opposing views among the Regents Science Teachers of notable interest to science educators are:

1. 68% of Regents science teachers disagreed that the current Regents exam is an appropriate summative assessment for their course.
2. The majority of Regents science teachers would change the *scope* AND *sequence* of their science courses if the Regents system would not exist.
3. 44% of Regents science teachers said they disagreed that the Regents system permits them to be creative teachers.
4. More than half (56%) of Regents science teachers believe that tension exists between what they know as effective teaching methods and what they feel they must do to prepare students for the Regents exam.

As with all self-report surveys, the data here should not be used to make curricular decisions or to place blame on the Regents system because many teacher beliefs showed negative trends. However, teachers were free to respond to this survey completely and anonymously and the data do indicate trends in Regents science teachers' beliefs that are not dissimilar to Tillotson (1998) study. As a result of the data in this study, the following concerns arise for the science education community:

1. What does it mean to science instruction when the majority (68% of respondents) of the respondents have negative views toward the state mandated standardized assessment system?
2. If teachers and their representative school districts would be in charge of their own systems of assessment, how would that majority (as reported) of Regents science teachers change the ***scope and sequence*** of their respective science courses?
3. When 44% of the respondents say they cannot be creative because of their Regents course, what kind of creativity, flexibility, and variability of instructional methods are students experiencing? Indeed, how flexible can teachers hope to be in designing instruction to meet the needs of ALL students? Perhaps more than any other question, this large number of negative responses toward being a *creative* teacher raises questions that merit discussion. The implications to such feelings or beliefs are many. For example, if such a large number of science teachers feel they cannot be creative in the art of teaching, how might that impact the implementation of a new, potentially more effective teaching method? What kind of pressures might new science teachers face when they feel they cannot be creative and try a new discrepant event, attempt a new twist to a tried and true lesson, or design a new activity?
4. What can science methods instructors do to encourage research-based teaching methods for beginning teachers in a system where 50% of the current science teaching population believes tension exists between effective instruction and the system they feel they are in?
5. What are the ramifications for national science education reform as other states develop similar mandated science assessments?

State curriculum, education and interests of each teacher, the socio-cultural situations of the individual student, attitudes of school districts and their administrators, and parents, are just a few of the variables that make standardized assessments difficult. And, with the myriad of variables that make up the system we know of as the *science classroom,* a one-size-fits-all final exam may be impossible to construct. Clearly, the exam system that functioned as the basis for this belief study has similar numbers of science teachers holding positive views as they do negative. These views influence student attitudes toward science and science learning, initial and prolonged motivations toward becoming a science teacher, and often result in teacher burnout.

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A COLLABORATION BETWEEN SCIENTISTS AND A SCIENCE EDUCATOR DEVELOPING WEB-BASED CURRICULAR ACTIVITIES

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Science instruction, whether Web-based or not, should provide opportunities for students to develop toward well-defined science goals and standards. These standards provide a vision and indicators for those involved in producing exemplary science instruction. National efforts such as *Project 2061's Science For All Americans* (1989) and *Benchmarks for Scientific Literacy* (1993), and the *National Science Standards* (1996) provide guidance for science curricular developers as they develop new instructional materials.

In general, science teachers want science students to (Berg & Clough, 1991):

- Perceive science as a set of meaningful, interrelated concepts, rather than mastery of many insignificant isolated facts;
- Convey positive attitudes about science indicating that science is meaningful and useful to them;
- Convey an understanding of the nature of science;
- Identify and solve problems effectively;
- Understand the connection of science to their community and personal lives;
- Demonstrate an awareness of the importance of science in many careers;
- Work cooperatively with other students as well as independently;
- Demonstrate constructive creativity and curiosity;
- Access, retrieve, and use the existing body of scientific knowledge in the process of investigating science-related phenomena;

- Communicate effectively;
- Set goals, make decisions, and self evaluate, and;
- Demonstrate logical as well as critical thinking.

During this enterprise of learning science, students should:

- Actively construct knowledge from what they observe and experience during the science activities;
- Ask questions, test ideas, interpret data, gather information, challenge ideas, physically and mentally manipulate objects and experiences;
- Actively participate in science;
- Identify problems as well as solve problems;
- Make decisions related to their science study and their science activities;
- View science as having intricate connections to their daily lives;
- Develop oral and written communication skills to display understandings of the fundamentals of science; and
- Use their scientific knowledge.

At the Eccles Institute of Human Genetics at the University of Utah, a science educator collaborated with a group of scientists to structure a new Genetic Science Learning Center Web site from scratch. The goals of the Genetic Science Learning Center were to:

- align genetic science learning activities with the National Science Education Standards;
- align genetic science learning activities with sound pedagogical instruction;
- make the Genetic Science Learning Center Web site different than a textbook; and
- make good use of the interactivity of the World Wide Web to present a "virtual environment" students could access from remote locations.

The intent of the Genetic Science Learning Center is to make a significant contribution to the development of a scientifically literate society where all citizens comprehend the genetic science concepts and processes required for personal decision-making, participation in public policy decisions, and economic productivity. Science educators nationally stress that textbook learning must be aided by inquiry activities and hands-on learning. In addition to facts, people need to learn skills for problem-solving, and critical thinking.

The science educator analyzed existing curricular materials, provided formative evaluation on new materials being created, and summative evaluation on existing instructional units. A series of seminars on science pedagogy and instructional technology topics were given biweekly by the science educator. The seminars were beneficial to the scientists in their comprehension of the issues involved in the delivery of science pedagogical content on the World Wide Web. The seminar topics included:

- Evaluating science education Web sites (Appendix A)
- Instructional design models (with an emphasis on the Dick and Carey model of instructional delivery and Gagne's nine events of instruction) (Appendix B)
- Curriculum development
- Structuring Web-based discourse with online forums (with in-depth discussion on differences between asynchronous vs. synchronous conferencing, and linear, tree-like forum structures vs. hierarchical branched structures)
- Designing Web-based instruction for special populations
- Web-based interactivity (including Java applets and role-playing simulations)
- Principles of good graphic design (Appendix B and Appendix C)
- Assessment (with an emphasis on rubrics)

- Structuring a Web site with templates
- Creating a Web site with Meta-tags for Internet search engines

The Genetic Science Learning Center Web site resulted in the creation of six main areas: Basic Genetics, Genetic Disorder, Genetic Thematic Units, Genetics in Society, Technology in Genetics, and Human Genome Project . The scientists and the science educator focused on developing the Technology in Genetics area of the Web site while the science educator was at the Eccles Institute.

The Technology in Genetics section contains three main areas: Lab Tools, Virtual Lab Tours, and Virtual Experiments. The Lab Tools area uses texts and graphics to show students tools that scientists use in their lab. Tools are grouped in the following categories: tools for measurement, tools for controlling temperature, tools for mixing, tools for separation, and safety. The Virtual Lab Tours Web page contains a series of QuickTime Virtual Reality interactive panoramas. The panoramas were photographed in a hybridization lab and a DNA sequencing lab. Once a movie appears within a Web browser, one can interactively pan left, right, up and down simply by clicking and dragging a mouse over the image. With an icon on a tool bar, one can also zoom in or out of the image to explore different areas of the lab. Hyperlinks are created on various objects in the panorama that transport a learner to a Web page describing how that object is used in the genetics laboratory. The Virtual Experiments area uses graphics and text to illustrate the sequence of events that occurs during hybridization, DNA sequencing, and cell injection laboratory experiments.

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Appendix A. Evaluating Science Web Resources

I. Science Content Issues

Content accuracy.
Does the site contain accurate, reliable information or is the site full of science misconceptions? (Is the "Physics of Star Trek" the real deal?)

Responsible author.
Is there a way to validate the information at the Web site? Is it clear who is responsible for the content? Can you contact the person who has written the information? Is there a way to e-mail a webmaster or other providers of the Web site's content to ask specific questions? Often, biographical information of the author(s) is contained as a link somewhere within the Web pages. If there doesn't appear to be any background information on the author, there is often a webmaster to e-mail for further information or to clarify questions about authority. Researching the authority of a Web site requires careful examination of the site.

Credentials of the author.
Is the content written by a scientist or another type of professional educator? Many "science Web sites" are being placed online by secondary school students. Is the content biased to one point of view? Some Web sites are known to advocate or support different causes and their biases are part of what we must keep in mind when we evaluate them. Grassroots environmental organizations and creationists produce online publications that are slanted in a particular direction, just as one would expect from an activist group. Look at the viewpoint of the Web site and analyze it.

Student engagement.
Does the content promote inquiry learning? Does the content encourage students to think and reflect? Are critical thinking skills needed to analyze and synthesize information? Is there a way students can be evaluated on their acquisition of knowledge from the Web site using an online quiz, an interactive animation, or some other type of assessment instrument or measure? Can students communicate with scientists or other field researchers directly from the Web site? Does the site offer any other types of interactive opportunities for students such as data sharing with other students or engaging in an interactive simulation? Are students encouraged to transfer the scientific knowledge that they learn at the Web site into a hands-on/minds-on science activity? Does the Web site encourage collaboration with other students? Are students encouraged to continue exploration and research with additional hypertext links at the Web sites? Are resources provided to assist students in developing their own online products or artifacts? Are there additional support materials for students to be involved in sustained inquiry activities both online and offline?

Using the strengths of the Web environment.
Does the Web site present material just like a textbook? If so, why not read a textbook? Are there special features included such as interactive animations (applets), graphical organizers, concept maps, or graphs? Are the media elements such as sound, video, animations, and graphics well done and meaningful?

A level playing field.
Does the content promote multicultural science education? Is the content biased toward a specific culture, gender or race? Is the Web site designed to provide learning disabled students access to all of the Web site's content?

Nature of the content.
Is the content comprehensive or cursory? Is the content appropriate for the grade level of the students? Is the math content appropriate for the grade level of the student? Is the content developmentally appropriate and relevant to your curriculum? Does the content support or enrich the curriculum? Is the content unique and not available elsewhere? For example, a Web site which displays daily sea temperature readings in a graphical form is unique.

Dynamics of the site.
Is the content at this Web site updated often? This is important for Web sites that contain scientific data. New data should be added periodically. Is this Web site permanent? Many Web sites change locations and often do not leave forwarding addresses. If you are going to link your Web site to someone else's, it is advisable to contact the owner of that Web site and ask them how permanent their site is.

References.
Are appropriate references and copyright statements included?

Reviews.
Has the content been through a peer review process? Has the content been edited for grammar and spelling?

II. Navigation

Linking within and outside of the Web site.
Can you move around the Web site easily? Are the navigation links visually obvious? Are there sufficient shortcut or hot buttons available?

Site organization.
Does the home page contain a well-labeled table of contents? Is a site map provided if the Web site is very large?

Consistent appearance within the Web site.
Are the navigation buttons consistent throughout the Web site? Are navigation button labels confusing or obvious? Will your students be able to intuitively know where to click their mouse in order to navigate within the Web site? Are the links clearly and accurately described? Hypertext links to other Web sites frequently do not work at a Web site that is not properly maintained.

Ease of browsing.
Do the hypertext links take you directly to the information or do you have to go through a series of mouse clicks to get to the information you want?

Searching.
Are search engines included within the Web site to assist you in finding the location of specific material?

III. Web Site Design

Visual appeal.
Do the design and style of the site enhance information delivery? Is it innovative? Is the design layout visually pleasing?

Thematic design.
Is the design related to the science content? Is the design consistent for each Web page within the Web site?

Clarity of presentation.
Are the pages uncluttered and cleanly designed? Appealing Web design features usually include tables and graphs. Some science Web sites use frames that can be unappealing and cluttered.

Flexibility.
Is the Web site designed to be viewed both by text browsers (Lynx) and graphics browsers (Netscape Navigator and Microsoft Internet Explorer)?

Obtrusive frills.
Does the Web site contain advertisements? Flashy advertisements may distract your students from the science content and create additional time to load the Web pages in your browser.

Stimulation.
Does the Web site get your attention? Will it get your students' attention and maintain their attention?

Appropriateness.
Is there appropriate use of graphics in the design layout?

IV. Performance

Page acquisition time.
Does the site take a long time to load with the type of connection you are using in your classroom? Students (as well as teachers) do not have much patience in waiting for Web pages to load large graphics. They will become distracted and lose interest easily. Using a Web harvesting

application such as WebWhacker can solve time-loading problems. Does the Web site offer you a text-only option? Are thumbnail versions of large graphics provided?

Connectivity.
Is the site usually accessible or is it difficult to connect to it? Some Web sites become very busy and difficult to access when new scientific discoveries are made. Some sites offer only a limited number of connections and might be running on a slow server. Also, accessing sites overseas can sometimes cause long wait times for Web page connecting and loading. Load time is important when considering the use of a Web site for a classroom demonstration. The best way to be safe with a demonstration is to harvest the Web site locally and view it from your computer's hard drive or another external mass-storage device (such as a Jaz or Zip drive).

Hardware speed.
Consider your connection speed when you access a Web site. Accessing large movie files with a 28.8 modem may not be worth your time unless they are extremely unique.

V. Multimedia Issues

Problems of size.
Multimedia files such as videos, sounds, and animations are usually very large files and can take a long time to download. It is recommended that you download these types of files ahead of time and have students access them locally from a hard drive or mass-storage device.

Required applications.
Many multimedia objects on the World Wide Web require a browser plug-in or a helper application. Some helper applications such as Shockwave requires an excessive amount of memory and time to load and run a multimedia animation in a Web browser. Make sure you have the appropriate helper application or plug-in loaded ahead of time before using these files with students. If you think a multimedia file is slow to load and run, so will your students.

Purpose of the multimedia.
Does the multimedia object promote learning or is it just a flashy novelty?

Real time communications.
Consider the pros and cons of using chat-rooms and video conferencing applications with students before engaging in these activities. Is the server you use available to the general public? Can anyone access your conversation? Is it worth the set up time to engage in such activities? Do you have enough bandwidth to maintain a reliable connection? Is this the only way you might be able to visit with a scientist or field researcher? Is this the only way your students can collaborate and share data with other students? Will using e-mail listserv or Web-based forums be a better alternative to live communication?

Appendix B. Instructional Design Models

Dick and Carey

One of the best known systematic design models is that of Dick and Carey (1990). This model focuses more on the process of design than on the individual design of specific lessons. One might identify the major components of their instructional design model as: Assessing Needs, Analyzing Content, Analyzing Audience(s), Setting Objectives, Identifying Measurement Approaches, Formulating Instructional Approaches, Developing or Incorporating Instructional Materials, and Evaluating and Revising Instruction. This last component is particularly dynamic, leading the systematic designer to make revisions to any or all previous components.

Gagné

Another frequently cited model of design is Gagné's Nine Significant Events Model. This model focuses more on the structuring and creation of individual instructional episodes. It identified nine important events in effective instruction:

1. gaining attention through stimulus change;
2. informing the learner of the objective to help learners perceive the importance and relevance of the instruction;
3. stimulating recall of prerequisite learnings in order to facilitate new learning;
4. presenting stimulus material in ways suited to the learner;
5. providing guidance for the learner that is appropriate to the complexity and difficulty of the material to be learned and the learner's skills and background;
6. eliciting a performance that demonstrates acquisition of the desired learning;
7. providing feedback about correctness of that performance in order to reinforce the new learning and extinguish inappropriate and competing responses;
8. assessing performance in order to evaluate the effectiveness of the instruction/learning;
9. enhancing retention and transfer by providing retrieval cues and recall strategies. (Gagné & Briggs, 1979)

Keller

Keller's ARCS Motivational Model (1983) emphasizes the motivational aspects of learning. The four major foci of the ARCS model are

1. Attention

Arouse and sustain curiosity and attention, with an emphasis on getting and sustaining, rather than merely directing, attention.

2. Relevance

Connect instruction to important learner needs and motives by addressing the question "How does this relate to my interests or goals?" Relate to current interests or past experiences of the learner and exhibit enthusiasm for the topic and its importance.

3. Confidence

Help learners develop confidence in their success and generate a positive learning experience by emphasizing learners' perception of their own competence and control and by emphasizing the expectation that learners will succeed.

4. Satisfaction

Choose rewards and reward structures in such a way that rewards (and consequences) appear to be logically derived and equitably distributed. Emphasize intrinsic rewards over extrinsic ones.

Appendix C. Developing Web-based Educational Materials

- Keep it simple.
- Identify your audience.
  - What size screen will your users view your Web site on?
  - What type of Internet connectivity do your users have? Fast T1 lines or slow 28.8 modems?
  - Will your resource be accessible for CD-ROM use?
  - Will special populations of students be using your Web site?
- Create an organizational site map of your Web site before you start writing Web pages.
- Define page layout, navigational conventions, and graphics before beginning site development.
- Start with logical conventions for site organization and file naming that will scale up smoothly as your site grows.
- Use relative links to navigate within your Web site (../../index.html). Avoid using absolute links within your Web site (http://www.ncsu.edu/servit/index.html).
- Use design attributes to let the user know that they are in your Web site. Use consistent background and navigation links throughout the entire Web site.
- Think outside the conventions of printed material. You can't assume web users will move linearly through material as they would in a book. So,
  - 1. Complete ideas on a single page, if possible.
  - 2. Offer multiple routes to the same information. (On the web, it is hard to predict where your user is coming from or going next.)
  - 3. Offer related ideas as links when the current idea is completed. Be explicit. If the next idea is clearly described in words, it helps the user choose to go there.
- Use thumbnail images for large graphics.
- Use ALT IMG tags when using graphics. This will decrease the loading time of your images and facilitate your Web page use with "text-only" browser users.
- Budget your time appropriately. If you think the job will take 40 hours to do, it might end up taking two or three times as long.
- Keep it simple.

INTER-INSTITUTIONAL EFFORTS TO DEVELOP A WEB BASED STS COURSE

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This paper includes the following information: There is (a) a theoretical context for this project, (b) a description of the development of this inter-institutional project, (c) an overview of the Web CT STS course developed, (d) the rationale for the structure of the course, (e) a list of factors that emerged as influences on students' success in this constructivist course and their implications for future development, and (f) questions for which the authors' would welcome readers' responses.

Theoretical Background

Novak's theory of education underlies the course structure. This is a new web-enhanced course to teach prospective and uncertified secondary science teachers about the interconnections between and among science, technology and society (STS) at three universities in the Florida State University System: University of South Florida (USF), University of North Florida (UNF), and University of Central Florida (UCF). The course itself is organized as a systematic inquiry. The course is based on current research in cognition, inquiry teaching and learning, and STS. Characteristics of the four learning environments described by the National Research Council (1999) - learner centered, knowledge centered, assessment centered, and community centered - are inherent in the course design. The course consists of two intertwined strands. One provides multiple opportunities to experience STS and to reflect on those experiences. The second provides the interaction within the community of learners to construct meanings from the experiences and to design relevant applications to classroom teaching. The instruction models constructivist teaching/learning strategies. The problems and projects examined are generated by the students in keeping with their respective contexts. Assessment is embedded in instruction and includes problem and project based performances with technology based components as appropriate, guided by rubrics.

Relation to Other Efforts

This course was built on what others have learned from previous reform efforts to introduce STS courses into teacher education at our own universities and other universities (Solomon & Aikenhead, 1994; Yager & Roy, 1993; Spector & Lederman, 1990). None of the courses for teachers examined to date, however, were web based. This new web based course is to be used at all three universities involved in its development. It reflects the spirit and substance of the reform movement while also reflecting local community based contexts. The course aligns with the National Science Education Standards, the Sunshine State Standards, and Florida's Educator Accomplished Practices.

Project Development

This inter-institutional collaborative project emerged in phases: In phase one, Marianne, Judy and Barbara spent many hours discussing their approaches and experiences teaching STS. They concluded that they could best serve their students by combining their expertise to create a web enhanced STS course that would be required of all secondary science education majors at USF, UNF, and UCF. This course would meet the state secondary science education certification requirement for either an STS course, or a history or philosophy of science course. They collaborated on a mini-grant proposal that was submitted to the Florida Collaborative for Excellence in Teacher Preparation through the University of North Florida.

In phase two, Barbara collaborated with Ruth, a computer expert, to develop a pilot Web site for Marianne and Judy to examine. The development process included pilot testing the site with students at USF in the fall of 1999. Ruth's knowledge of computers and instructional design for the web guided the adaptation of the face-to-face five credit STS course at USF to the web. That course had been developed by an interdisciplinary team, and was taught and revised over five years with support from Title II Eisenhower funds. Procedures for developing electronic products for STS, part of a graduate STS course at UNF that was developed with NASA funds, were incorporated into the web site. Ruth put the materials on the web and provided students with technical assistance on tasks on their computers. As Ruth and Barbara generated ideas and tested them out with students, students became collaborators in the course development.

The syllabus currently posted on the site reflects what happened when the original face-to-face class design confronted the realities of distance learning using WebCT and live undergraduate students. The twelve students in the pilot test included traditional preservice secondary science education majors and students from other colleges on campus using this course to fulfill a University core requirement for a major issues - major works course. The class met seven times face-to-face out of the 15 week semester: five times on campus and two times at a model middle school that implements STS. Plans for the future at USF include testing the web site as a distance learning course with no on campus meetings.

Phase three of this collaboration began in November 1999 as Marianne and Judy examined the web site to determine what of it they would use for their students, and how they would use it. The description of the web site below indicates why the site is flexible enough to be used in a variety of ways. Judy will pilot the web site with her preservice secondary majors as a full distance learning course. The first class will meet on campus and the rest of the work will be done as independent study using the web site. The assignments presently on the site will be modified to reflect a three credit course. Marianne will use the web site to augment the existing STS course for inservice teachers at her university this spring and will incorporate the course as a three credit web enhanced course in a new developing preservice program for middle school teachers.

Course Overview

This learner centered Web CT course is structured as an open-ended inquiry into the question, "What is STS and how does it relate to science teaching?" Students are invited to conduct a self-guided investigation in a virtual resource center on our Web site. The center includes print matter, videotapes, graphics, interactive media, and links to relevant sites on the World Wide Web. These are arranged in three bins: (a) the nature and history of STS, (b) specific examples of STS, and (c) teaching STS. The division into separate bins (categories) is artificial and arbitrary for the convenience of study. Students also gather data from a variety of public media sources of their choosing each week, and site explorations in the community to business and industry organizations, informal education agencies, a school that is a model for STS teaching, and other local schools.

In 1995 Paul Hurd said, " The unique thing is that it takes time and a lot of interactions to find out that there is a relationship among science, technology, and society." This Web site makes a multitude of STS interactions available to students from which they can construct their personal understanding of this relationship. There are 12 tasks described in the syllabus to assist students in organizing, displaying, analyzing, and interpreting their data, as well as to provide scaffolding through successive additions of concepts and skills. Each task is both a learning opportunity and an assessment opportunity. All require applying knowledge to real world situations. Every task description ends with a statement indicating what the student is intended to achieve intellectually by doing that task. Within the descriptive paragraphs are links to self-assessment criteria for the task and links to prior knowledge that might be needed to do the task. For example, one of the metacognitive tasks asks students to construct concept maps every three weeks illustrating how they are integrating new information into their cognitive frameworks. A link in that paragraph takes students to directions for making concept maps. Another link takes them to a computer concept mapping program and directions for its use. Thus if their prior knowledge did not include constructing concept maps, they have guidance immediately available to them on an "as needed basis."

Some tasks result in products to be used by others for teaching STS in the future. Students post their products on our Web CT site. They are moved to a non-Web CT site at the end of the semester to add to a growing collection of student products available to the profession.

The course communication center is used by students as the vehicle for sharing their experiences and the way they are making sense of these experiences. It allows for both synchronous and asynchronous communication. The asynchronous Forum built into Web CT is the primary communication vehicle used. Students post reflective journals each week, an item from the media, concept maps, and videotape highlights in individual dated forums. They are required to respond to each other's postings by critiquing what was written and evaluating the reasoning and evidence presented.

Since they are selecting their own pathways through the virtual resource center, comments from a peer about a particular item often serves as a stimulus for another individual to investigate that item. Many idiosyncratic pathways develop in the learning community. Sharing these pathways, rationales for them, and their impact helps a prospective teacher recognize that what was a logical and functional pathway for him/herself is only one of many productive ways available to pursue learning.

Procedures inherent in this Web site provide students with three sources of feedback to guide their learning: (a) themselves, (b) their peers, (c) and the instructor. The most immediate feedback is that which they give themselves by determining to what extent they are able to make sense of the items in their chosen pathway. They determine what additional, or alternate, items would be helpful to make sense of an idea. The self-assessment criteria provide an external frame of reference by which to measure their interpretations and applications of newly constructed ideas. Freedom of choice and time allows them to continue gathering data until satisfied with the meanings they have made.

During the "conversations" in the forums students explore each other's perspectives, seek evidence for positions presented, and generate new ways to think about STS. These interactions provide peer feedback to individuals regarding the clarity of their thinking and the functionality of their products as they are developing. The professor gives feedback as one of the co-learners in the community, not as the final authority.

Thus the course is recursive. Learners explore resources, gather data, make interpretations, share their interpretations through Web CT's forum, receive feedback from this learning community, explore more resources, reinterpret their data, and share their ideas again. The process is repeated each week as learners' make more connections to deepen the understandings they are constructing and generate their personal grounded theory of STS. While progressing through learning opportunities, they build on their own prior knowledge and experience the interactive nature of learning as they revise and improve the quality of their thinking and understanding.

The communication center also has email available for people to communicate with each other and the instructor privately. Small assigned heterogeneous study groups and groups voluntarily organized to do tasks are free to use the chat rooms built into WebCT to communicate synchronously. This is particularly useful when they are developing a product cooperatively.

Rationale for Course Structure

This course was structured as an open-ended inquiry, because future teachers need to understand that the way scientists learn about the natural world is a fruitful way for them to learn about STS and science teaching. When scientists conduct original investigations, they choose how to proceed. The priority for all decisions about how to construct this Web site, therefore, was maximizing opportunities for students to make choices. Choice enables them to control their own construction of knowledge, empowering them to take charge of their own meaning making (Novak, 1998). They determine their own learning pathway, not restricted in sequence or time by the instructor. Students may elect to learn deductively, inductively, or a mixture of the two. The site accommodates both sequential and global types of learners. Additionally, the site design enables and encourages students to use their own learning experiences as a data source from which to learn how to teach STS.

Instructional design decisions in structuring this site included the continuity of graphics and text elements and navigation aids to facilitate intuitive flow from page to page. Uniformity of icons, type fonts, titles, and page layouts create a continuity of appearance throughout the site. Icons were chosen to indicate a particular type of resource. Whenever appropriate, symbols typically recognized by professionals in science education were used as icons. Since students create their own navigation pathways, decisions about links to enable students to return to pages at will were critical. Decisions about opening successive windows, chunking information, numbers, kinds, and arrangements of icons per page, and types of file formats for resources are some of the technical considerations related to issues of learner/instructor control.

Emergent Factors and Implications

Preliminary findings from an emergent design qualitative study of the pilot test of this Web CT site revealed factors that influenced students' learning. To the extent they possessed the following intellectual tools, the potential for optimum learning from this site was increased: Tools for (a) systematic inquiry; (b) thinking about their own thinking (metacognition); (c) self-assessment; (d) time management and planning; (e) critiquing writings and evaluating reasoning and evidence; (f) cooperative learning; and (g) using the computer technology and software.

These findings suggest the need to develop (a) a prerequisite course in which students could develop these tools, or (b) increase the number of credits assigned to this course and provide extensive directions for learning to use these tools during this STS course. These tools are essential for success in this STS course and for the career-long learning advanced by the National Science Education Standards (NRC,1989).

This web course development experience raises many of the same questions science educators are struggling with throughout the country. For example, what depth and breath of understanding is reasonable to expect from preservice teachers whose entire learning career has been learning via a reductionist/mechanistic paradigm of knowledge transmission? And its sequel, what depth and breadth of understanding is reasonable to expect from in-service teachers who are new to the paradigm of reform? In what sequence should learning experiences be offered to capitalize on what we know about the role of prior knowledge in learning?

The authors would appreciate feedback on the web site design presented here and insight to how you are thinking about responses to the preceding questions.

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WHAT WE KNOW ABOUT OUR FUTURE MATH AND SCIENCE TEACHERS

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As a Collaborative for Excellence in Teacher Preparation (CETP) program of the National Science Foundation (NSF), the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT) has as a main goal to strengthen teacher preparation in math, engineering, science and technology. One major way OCEPT identified to achieve that goal was to engage faculty currently teaching undergraduate science and mathematics courses in a critical examination of their instructional practices. Through a variety of interventions, OCEPT hopes to encourage the particular kinds of instructional practices advocated by Oregon State and National educational reforms among these faculty. The OCEPT Student Survey is one means of gathering information about the types of methodologies used by undergraduate faculty in teaching math and science courses.

When the OCEPT project began in 1997, no information was available about the number and variety of undergraduate math and science courses students completed before entering teacher education programs in Oregon. The Collaborative also had no notion of the types of instructional practices students were exposed to in these classes. Additionally, little was known about whom students felt had encouraged them to consider teaching as a career. To begin to fill that void, a pilot survey was developed and administered to students entering teacher education programs across the State in 1997-98.

After analysis of the data collected last year, further review by faculty involved in the Collaborative, and a reexamination of the goals and objectives of OCEPT, a revised student survey for 1998-99 was developed. Specifically, the 1998-99 OCEPT Student Survey sought to collect data on the following:

1. Math and science college course work completed, including:

- Number of college-level courses completed in mathematics and science, with science broken into categories (e.g., astronomy, biology, chemistry, etc.)

- Whether those courses had a lab or field component
- College where the majority of the courses were taken
- Whether the majority of the courses were taken in Oregon
- When the course work was completed (before 1990, between 1990 and 1994, between 1995 and present)

2. Undergraduate mathematics and science classroom experiences, including:

- Extent to which specific classroom experiences were incorporated into undergraduate mathematics and science classroom (e.g., project work, cooperative learning, journaling, use of computer technology, etc.)
- The kinds of technology students were required to used in association with math and science courses
- Solicitation of comments students may have concerning whether these college experiences contributed to their preparation as teachers

3. Advising and support, specifically:

- Whether students knew where to get information regarding teaching as a career, before, during, and after college
- Who might have encouraged the students to pursue studies in math, science and/or teaching

4. Demographic information, such as:

- Gender
- Ethnicity
- College background [level, major, authorization level(s), endorsement area(s)]

Copies of the questionnaire, instructions for administration, and informed consent forms were sent to all 16 institutions of higher education in Oregon which have teacher preparation programs. Faculty were asked to administer the survey to all students admitted to teacher education programs between June and December 1998 (that is, undergraduate seniors and postbaccalaureates), preparing for licensure at the early childhood (ECE) and elementary levels and for math or science authorizations at the middle and/or high school levels. Fourteen colleges and universities participated in the survey administration. In all, 503 completed questionnaires were analyzed, representing 158 undergraduate ECE/Elementary preservice teachers, 227 post-baccalaureate ECE/Elementary preservice teachers, and 118 preservice teachers seeking a math or science endorsement for teaching at the middle or high school level. This last group was comprised of both undergraduate and post-baccalaureate students.

Content validity of the instrument was determined by a panel of college math, science and education faculty familiar with (a) National and State mathematics and science reform efforts, (b) teacher education programs, and (c) the goals of the OCEPT project. Both the pilot and current instruments were designed based on the National math and science standards for teaching (National Council of Teachers of Mathematics, 1986, 1991, 1995; National Resource Council, 1992), instruments used by other Collaboratives for Excellence in Teacher Preparation projects (The Rocky Mountain Teacher Education Collaborative, 1996), and an instrument developed by the American Association for the Advancement of Science Project 2061 (Champagne, 1989).

To gain some measure of reliability, a group of 18 post-baccalaureate ECE/elementary preservice students was given the survey twice, over the course of a month. Using a conservative alpha of 0.01, paired t-tests showed no significant difference in responses for each section of the questionnaire and for most individual items on the survey. There were two items, when the analysis is taken question-by-question, that did indicate a significant difference between the two survey administrations. One item concerned working on problems and projects with other students in science class (p=0.02), and the other was in providing opportunities to "be" a mathematician (p=0.02). The actual difference in the means in both these cases was about 0.5 on a one to five scale. The variances were also large. The means and variances for the science item were 3.6 and 2.3, respectively, for the first administration and 3.1 and 2.1 for the second. The means and variances for the math item were 1.2 and 0.3 for the first administration, and 1.8 and 1.0 for the second. Each item of the list of 12 classroom experiences is rated by the students for math and for science. Because there was a lack of a statistical difference when the items were applied to the alternate course work, rather than ignore the findings for these two items, these data should be viewed cautiously.

Results

To analyze the data, the respondents were initially examined as belonging to one of three separate groups: undergraduate early childhood and/or elementary preservice teachers (Group 1), post-baccalaureate early childhood and/or elementary preservice teachers (Group 2), and students seeking an endorsement in math and/or science for the middle and/or high school level(s) (Group 3). (Because of low numbers of students belonging to Group 3, a separation between undergraduate and post-bac students was not initially made.)

An item was added to this year's questionnaire to ascertain *when* the students took the bulk of their math and science college courses. As will be noted below, there is a time lag between when the undergraduates and post-bacs completed the majority of their course work, and this may have an impact on the types of classroom experiences to which they were exposed. Because of this, even though the sample sizes were small, Group 3 was broken into two subgroups: middle/high school undergraduates (Group 3a) and middle/high school post-bacs (Group 3b) for some analyses.

Group 1: Undergraduate ECE/Elementary

One hundred fifty-eight respondents were preservice ECE/Elementary teachers in an undergraduate teacher preparation program. The majority of these students were white (89%) and female (92%). Most of these students took the bulk of their math (84%) and science (88%) course work in Oregon and since 1995 (88% and 92% for math and science, respectively). Prior to attending college, 41% of them were encouraged to pursue studies in math and science, mostly by family members (25%) or a teacher (31%). Counselors appeared to have exerted little influence in this area, with only 4% of the respondents indicating that counselors had encouraged them to consider these content areas for further study in college. During college, 33% were encouraged to consider teaching as a profession. Influencing people seemed to come almost equally from two categories: a math faculty member (15%) and another student (11%). No one mentioned that a science faculty member had suggested teaching as a career choice.

On a scale from 5 to 1 (with 5 being low and 1 being high), students indicated they were most able to " know where to get accurate and timely information about becoming a teacher" while in attendance at a four-year institution (mean of 1.9). This is not surprising since the students are enrolled in an undergraduate teacher preparation program. One would expect that being in a teacher education program, students would have easy and ample access to persons who could provide any needed information concerning a teaching career. The ranking for getting information before entering college had a mean of 3.1, indicating a rather mediocre rating. However, this does not take into account whether students had actively sought information from a guidance counselor or other source.

Most of the students in Group 1 had taken between one and four math courses, with 22% having taken at least one course, and 15% taking five or more. Almost one-fifth (18%), however, indicated not having any math credits. This group averaged 2.78 math classes. The average number of science classes taken by Group 1 students is 3.5. The most likely science course(s) to have been taken was in the biological sciences (70% had some biology course work), followed by environmental science (36%), computer science (31%), and geology (24%). It was pleasing to see that 20% of these preservice ECE/elementary teachers had taken at least one course in physics and 23% had taken at least one course in chemistry.

Of concern is the low number of labs or fieldwork that was included as part of their course work. Although 70% of the students reported taking at least one biology course, only 51% of those had a lab/field experience associated with it. The percentage of these types of experiences drops below 20% for the remainder of the sciences. Likewise, while 82% of the students noted having taken math course(s), only 9% of those had a lab component. The current emphasis in both National and Oregon State standards is on teaching using an inquiry approach. Without having much personal exposure to any type of laboratory or field experiences, it is difficult to imagine that the preservice teachers will be comfortable using that type of delivery model.

To get some measure of the experiences the students might have had in their math and science classrooms, a series of 12 questions was listed for each. The students were to respond to the experiences on a five-point scale, with one representing "not at all" and five being "frequently." Table 1 lists the math items and the mean for each.

Table 1

Listing of means of the various Groups' responses on a scale of 1 to 5, from "not at all" to "frequently," to their math classroom experiences

	Group Means			
Item	1	2	3a	3b
encouraged me to work on problems and projects with other students	3.7	3.0	3.8	2.6
used a variety of approaches to help me and other students learn (group work, lecture, field-based work, hands-on labs and demonstrations, etc.)	3.5	2.8	3.5	2.2
provided a variety of ways for me to demonstrate what I learned	3.0	2.5	3.4	2.1
helped me to make connections between the course material and the "real world"	3.5	2.8	3.4	2.4
provided frequent feedback on my work that helped me improve my learning	3.5	3.0	3.7	2.8
made learning goals very clear	3.7	3.4	4.0	3.1
emphasized my understanding of "big ideas" or concepts rather than isolated facts and information	3.4	2.9	3.6	2.8

Table 1 (con't.)

Listing of means of the various Groups' responses on a scale of 1 to 5, from "not at all" to "frequently," to their math classroom experiences

	Group Means			
Item	1	2	3a	3b
expressed the belief that I could learn and be successful in their classes	3.8	3.1	4.2	3.0
provided opportunities for me to "be" a mathematician (posing my own questions, investigating problems, analyzing data, developing theories)	3.0	2.4	3.5	2.2
used computer technology in ways that enhanced my ability to learn	2.5	1.8	2.8	2.1
required me to reflect on my learning through writing, journaling, etc.	2.4	1.7	2.3	1.4
shared with the class their reasons for choosing their teaching strategies	2.6	2.0	2.6	1.6

The highest-ranking experiences in math were feeling they could be successful (mean of 3.8), being encouraged to work on problems and projects with others (3.7) and having clear learning goals (3.7). Required reflection on one's learning (mean of 2.4), uses of computer technology (2.5), and explained teaching methodology (2.6) had the lowest means.

As seen in Table 2, in science classrooms, the items receiving the highest ranking means were those where the instructor used a variety of approaches to help a student learn (3.6), made the material relevant (3.6), had student work on projects and problems with others (3.5), and had clear learning goals (3.5). The same three items ranked lowest in math were also ranked the lowest in science (reflecting, 2.1; explained teaching methodology, 2.3; and use of computers, 2.5). These rankings support that the experiences students are receiving in their college math and science courses are not in line with the suggested National teaching standards.

Students were given a checklist and asked to mark which kinds of technology they were required to use in association with their math and science course work. See Tables 3 and 4 for the percentages of students using the various types of technology associated with math and science classes, respectively. For math courses, the type of technology used most often was graphing calculators (58%), followed by word processing (30%), graphing utilities (25%), and spreadsheets (20%). The other types of technology had response rates of between 1-18%. In science classes, the most common form of technology used by the students was word processing (59%), followed by microscopes (58%), world-wide web (43%), computer-based simulations (29%), and e-mail (26%). The rest yielded responses between 3-17%. What this exposure to technology means in terms of the ease and frequency with which these preservice teachers will use technology in their own classrooms remains to be investigated.

Table 2

Listing of means of the various Groups' responses on a scale of 1 to 5, from "not at all" to "frequently," to their science classroom experiences

	Group Means			
Item	1	2	3a	3b
encouraged me to work on problems and projects with other students	3.5	3.2	3.7	3.4
used a variety of approaches to help me and other students learn (group work, lecture, field-based work, hands-on labs and demonstrations, etc.)	3.6	3.5	3.8	3.6
provided a variety of ways for me to demonstrate what I learned	2.9	2.6	3.2	2.8

Table 2 (con't.)

Listing of means of the various Groups' responses on a scale of 1 to 5, from "not at all" to "frequently," to their science classroom experiences

	Group Means			
Item	1	2	3a	3b
helped me to make connections between the course material and the "real world"	3.6	3.2	3.7	3.4
provided frequent feedback on my work that helped me improve my learning	3.1	2.8	3.1	3.1
made learning goals very clear	3.5	3.3	3.7	3.4
emphasized my understanding of "big ideas" or concepts rather than isolated facts and information	3.3	3.1	3.5	3.3
expressed the belief that I could learn and be successful in their classes	3.4	3.0	3.8	3.3
provided opportunities for me to "be" a scientist (posing my own questions, investigating problems, analyzing data, developing theories)	3.0	2.6	3.0	3.1
used computer technology in ways that enhanced my ability to learn	2.5	1.7	2.5	2.3
required me to reflect on my learning through writing, journaling, etc.	2.1	1.8	1.9	2.2
shared with the class their reasons for choosing their teaching strategies	2.3	1.7	2.3	1.9

Table 3

List of the kinds of technologies students used in association with their college mathematics courses and the percentages of responses by Group.

	Group Percentage			
Item	1	2	3a	3b
word processing	30	23	28	29
spreadsheets	20	15	9	27
e-mail	18	11	15	14
world wide web	17	7	19	12
STELLA	1	2	3	2
statistics programs	11	19	3	37
graphing utilities	25	15	34	37
geometric sketchpad	8	5	3	7
graphing calculators	58	39	72	62
real-time data acquisition	2	8	2	3

Table 4

List of the kinds of technologies students used in association with their college science courses and the percentages of responses by Group

	Group Percentage			
Item	1	2	3a	3b
word processing	59	44	50	67
spreadsheets	17	12	16	40
e-mail	26	15	13	26
world wide web	43	14	34	23
STELLA	3	1	0	5
microscopes	58	49	15	70
computer-based simulations	29	15	16	23
graphing calculators	13	11	9	27
real-time data acquisition	7	11	9	24

Group 2: Post-baccalaureate ECE/Elementary

Two hundred twenty-seven respondents were preservice elementary teachers who had already completed a bachelor's degree. As with the undergraduates, most of these students were white (92%) and female (85%). While the majority of the Group 2 students completed their math and science course work in Oregon, the percentages were lower than for the Group 1 students. Seventy-one percent had completed their math in Oregon, and 65% had completed the bulk of their science courses in Oregon, as well. The time-span over which most of these preservice teachers had completed their course work was much more varied, as would be expected since many of these students typically enter teaching as a second career choice. Twenty-one percent completed their math course work prior to 1990, 37% between 1990 and 1994, and 42% after 1994. The percentages shift somewhat for science, with 28% completing their course work prior to 1990, 43% between 1990 and 1994, and only 29% having taken their courses after 1994.

Similar to their undergraduate counterpart, 37% of the post-bacs felt encouraged to pursue studies in science and math. Members of their families and teachers ranked the highest in being the influential force (28% for family and 22% for teachers). In contrast to the undergraduate counterparts, fewer Group 2 students were encouraged to consider teaching as a profession during college. No particular group was a predominant influence: 6% of the respondents indicated other students suggested teaching, as compared with 10% for math instructors and 8% for science instructors. Graduate assistants were mentioned as influential by 1% of the respondents.

The mean responses for knowing where to get information regarding teaching as a career prior to entering college was very similar for Groups 1 and 2, with Group 2 's mean being one-tenth "lower" (3.2) on a scale of 1 to 5. (Recall that for this scale, one was high and 5 was low.) Group 2's mean for getting information while in college was a half-point "lower" (2.4). Since less post-bacs felt encouraged to consider teaching as a career during college, and were not enrolled in teacher preparation programs, this lack of a discrepancy in the means is interesting to note.

The academic preparation in mathematics and science of the post-bacs differed from that of the undergraduates. On the average, the post-bac group took one more math course (mean of 3.5) than the undergraduate EDE/Elementary group (mean of 2.78). The number of math courses completed by Group 2 students was pretty disparate, with 14% indicating they had not received any math credits, 9% having one, 17% having two, and about an even amount (10-14%) for 3-6 courses. Ten percent had taken between 7 and 15 math classes.

Group 2 students, on the average, took twice as many science courses as the corresponding undergraduates (means of 6.7 and 3.4, respectively). This average is much higher than indicated from last year's respondents (Morrell, et al., 1998). No undergraduate programs, with the exception of those with a mathematics major, in the State require six or seven math courses (OCEPT Advising Guide, 1999), and a large percentage of these respondents did not indicate they were mathematics majors as undergraduates. Thus, the reason for the rise in science coursework is not apparent. As with Group 1 respondents, the most likely science course to have been taken was in the biological sciences (68% had some biology course work, with 43% having two or more classes), followed by computer science (50%), and environmental science (41%). Approximately 22% of the students indicated having taken at least one physics course, and 36% had at least one chemistry course. Although the percentage of these courses having a lab or field component is also low, the percentages are higher than for the undergraduates. Sixty-three percent of those in biology had a lab/field experience associated with the course(s). The percentages are between 20 and 30 for computer science (34%), chemistry (29%), math (28%), and geology (27%). Astronomy, environmental science, general science, and physics had labs reported between 10-17% of the time.

The responses for the classroom experiences were quite different for the post-bacs than for their undergraduate counterparts. While the ranked order of occurrence of the items is similar, the averages are not, as indicated in Table 1. The highest mean for math was for having clear learning goals (3.4), followed by a feeling of being successful (3.1), receiving frequent feedback (3.0), and working on problems and projects with others (3.0). Reflecting had the lowest average response (1.7), followed closely by computer technology (1.8), and making teaching methodologies explicit (2.0). Although these three items were ranked lowest by Group 1 as well, the lack of frequency with which some of these practices occurred, particularly technology and reflecting, may be a result of the post-bacs having completed a majority of their classes more than five years ago when such practices were not as common.

The science experiences were also ranked lower than the undergraduates. (See Table 2.) The most frequently occurring experience was using a variety of approaches to help students learn (3.5), followed by working on problems and projects with others (3.2) and "real world" content (3.2). The least common classroom experiences were using computer technology and reflecting, the means for both being 1.7.

Again, the differences in the use of technology may be a reflection of the time period during which students completed their math and science course work. Please refer to Tables 3 and 4. For math courses, the type of technology used most often was graphing calculators (39%), followed by word processing (23%). The other types of technology had response rates of between 2 and 19%. In science classes, the most common forms of technology used by the students were microscopes (49%) and word processing (44%). The remainder ofthe tools was used by between 1-15% of the students.

Group 3: Undergraduate and Post-baccalaureate Middle/Secondary

A total of one hundred eighteen students planning to become middle/secondary school math or science teachers responded to the survey. This Group comprised 32 undergraduates and 86 post-bacs. Group 3 was similar to the other two in terms of ethnicity (95% were white), but showed the greatest diversity in terms of gender (42% female, 58% male). About three-quarters of the students were educated in-state (71% for math; 75% for science). As with the ECE/Elementary Groups, there was a considerable time difference between when the undergraduates and post-bacs completed the bulk of their content area course work. For math and science, respectively, 3% and 0% of the undergraduates completed these courses before 1990, 3% and 13% between 1990-1994, and 94% and 87% since 1995. Conversely, the post-bacs completed 29% of their math and 32% of their science courses prior to 1990, 47% and 41% between 1990-1994, and 24% and 27% of the content courses since 1995. Because of the differences seen in classroom experiences in Groups 1 and 2, we decided that for the analysis of Group 3's classroom experiences, we should analyze the findings for the undergraduates (Group 3a) and the post-bacs (Group 3b) separately.

These Group 3 preservice teachers were the students who felt most influenced to pursue study in math or science prior to college (56%). Also high were the percentages of those who felt influenced by a teacher (40%) and by family members (47%). Again, counselors were ranked low (4%). During college, a bit less than a third (32%) felt influenced to consider a profession in teaching. The sphere of influence here was very similar to the other two groups: other students (13%), science faculty (8%) and math faculty (14%). These students felt they knew more strongly where to get information regarding a career in teaching during or after college (2.5) rather than prior to college (3.5). Again, this suggests the need to educate our high school counselors to make teaching a visible career option.

Nine percent of the students in Group 3 reported having had no math classes. A quarter of them had 7 or more math courses. Sixty percent of the students were fairly evenly distributed between having completed one to six courses. Twenty-five percent indicated having a field or lab component with their math course(s). In the sciences, biology was the most common field, with only 22% of the respondents not having any background in biology. The next most common area was chemistry (63% having completed one or more courses), followed by physics (56%) and computer science (56%). Group 3's background in astronomy, environmental science, geology, and general science was very closely aligned with those in the other two groups. Field work or lab components were more prevalent with this group than the other two. Fifty-six percent of the respondents indicated a lab or field component associated with biology courses, 52% with chemistry, 36% with physics, and 34% with computer science. The other fields varied between 11-26%. Given the stronger science background of this group, perhaps upper-division level courses are more commonly associated with laboratory and fieldwork.

Group 3's perceptions of the frequency with which various instructional practices occurred in their math and science classrooms can be found in Tables 1 and 2. Group 3a (the undergrads) are similar to Group 1 in their ratings of their math classroom experiences, although the rankings differed. Group 3a recorded the highest ratings for math experience than any of the groups for either math or science. The highest item was feeling they could be successful (4.2), followed by clear learning goals (4.0), working with others (3.8), and receiving frequent feedback (3.7). The science classroom experiences for Groups 3a and 1 followed a similar pattern with rating that were close but rankings differing. Group 3a's highest two items tied with a rating of 3.8: variety of approaches and believing they could learn and be successful. The next three highest items were also ties (3.7): working with others, connecting the course to the real world, and clear learning goal.

Group 3b (post-bacs) had the lowest math classroom experience ratings of all four groups. Their highest scoring item was clear learning goals (3.1), followed by feeling they could be successful (3.0), with emphasis of concepts and providing frequent feedback tying for third with a rating of 2.8. Their science classroom experiences were rated as most similar to Group 1 and higher than Group 2 but generally lower than Group 3a. The top ranked science classroom experience was using a variety of approached (3.6), followed by three items each receiving a rating of 3.4: working with others, making connections to the real world, and having clear learning goals.

For both Groups 3a and 3b, the lowest rated items in both math and science classroom experiences matched those of Groups 1 and 2; namely, use of computer technology, reflecting on learning, and sharing reasons for teaching strategies.

Group 3, collectively, seems to have had the most exposure to technology in their math and science classes. See Tables 3 and 4. It is interesting to note that only 15% of the Group 3a indicated exposure to microscopes as compared with 70% of Group 3b. Also of interest, is the increased use of statistics programs of Group 3b and the low exposure of Group 3a. Finally, since more than 50% of the Group3b students indicated completing their coursework prior to 1994, it is worthy to note that 62% indicated using graphing calculators in math classes.

Discussion and Implications

The 1998-1999 OCEPT student survey data have highlighted several areas--some that were noted from last year's survey and some that are new because of the changes made to this year's questionnaire. Mirroring last year, the findings indicate that a) the student body in teacher preparation programs is still lacking in diversity, and b) the content background in math and science is quite varied. Additionally, the data suggest that there is considerable room for improvement in college teaching methodologies in the directions sought by current reforms. Several institutions have instituted specific programs to increase diversity on our campuses and to encourage articulation between community colleges and four-year colleges and universities. A survey was conducted to determine what science and math requirements are for both undergraduates and post-bac students at Oregon institutions (OCEPT Advising Guide, 1999). At least one institution has recently changed the science requirements for undergraduates (the University of Portland). Future surveys will be used to assess the effectiveness of these changes and refocusing.

This survey was the first to gather information on lab and fieldwork experiences of preservice teachers. The lack of laboratory and field experiences is a cause of concern. The preservice teachers are expected to engage their students with hands-on activities and inquiry-type lessons. Given the evidence of large amounts of math and science anxiety among ECE/Elementary teachers, and further given they have little to no exposure to the types of methods suggested by the current standards, it is highly improbable that the preservice teachers will employ these methods. While those seeking an endorsement in math or science seem to have greater exposure to lab and field activities, the amount of these experiences is still low. Being taught by lecture tends to perpetuate itself, which may be why many middle and high school math and science teachers still adhere to "old" teaching methods. In addition, just because a student has been exposed to a lab course does not mean the lab was an inquiry-type rather than a more traditional, "cookbook" style lab. OCEPT workshops have exposed faculty to inquiry methods. Again, time is needed to see how effective those interventions have been.

One new area investigated that has raised a number of questions is the period of time when the preservice teachers completed the bulk of their math and science course work. In general, the post-baccalaureate students tended to have taken their classes prior to 1995. This prompts two areas of concern: Have the types of classroom experiences in undergraduate math and college science courses changed over time? Given most post-baccalaureate education programs are heavily concentrated on education courses, what kind of impact can we have on how these preservice teachers will ultimately teach math and science in their own classrooms?

Even though the desired experiences for math and science classes seem to be increasing in frequency over time if one compare the undergraduate ratings with those of the post-bacs, the experiences are still not occurring at a rate that would be in concert with the national standards. Though a few of the experiences were edging toward a "four" on the scale, most were still occurring rarely. The responses to the open-ended question concerning how/whether the preservice teachers' college mathematics and science courses have contributed to their preparation as teachers suggest that the students' perceptions of the connection between these classes and their role as teachers varies. Those that did feel their course work had been advantageous tended to stress the content that was presented. Students felt the courses either further explained or provided the basic content information teachers need to know. Effective methodologies are not being garnered from these classes. There is a need to continue to educate and assist current college faculty in implementing both the teaching and assessment standards into their classes. The faculty need to be made aware of the resources that are available to assist them in strengthening their instruction (for example, Ganem, 1993; Hartman, 1995; Orzechowski, 1995).

Of concern is the second area noted above. Generally, post-bac programs provide students with general methodologies that can be used with students. It is generally assumed that their content in math and science are adequate (as evidenced by the required tests for licensure). If these students have not been exposed to the methods reform reports suggest they employ, this raises the questions of whether pedagogical content knowledge is really a domain and what kind of an impact we can have in a one-year program on how these preservice teachers will present math and science to their students.

The role of technology in teacher preparation programs is still unclear. More technology seems to be associated with math and science courses, though students feel at least their experiences with computers have not "enhanced their ability to learn." Given the spread of schools that are now hooked up to the Internet, having teachers familiar with the world-wide-web and the use of e-mail is a given. In addition, many schools have received or have purchased classroom sets of graphing calculators. Again, teachers need to know how and when to use these with students. It seems intuitive that the more technology is used in conjunction with math and science college classes, the more comfortable and knowledgeable students will be in using the technology with their own students. Besides content courses, some of the technology can be used in conjunction with methods and other education courses. How frequently this is occurring has not been assessed.

Counselors and teachers need to realize how much of an impact they have on student career decisions. Few students are being encouraged to pursue studies in math and science. However, there does seem to be a relationship between teacher encouragement and pursuing such studies. More than half of the secondary preservice teachers who are seeking endorsements in math or science were encouraged to further their studies in these areas in college by a teacher.

There is also a lack of a strong influencing person encouraging someone to consider teaching as a career. Is the desire to teach may self-motivating? What did influence students to pursue a teaching career, since family, friends, teachers, and counselors appear to have a minimal to little effect?

Finally, college faculty need to take a more active role in encouraging teaching as a profession. While no faculty wants to encourage someone to opt out of majoring in his/her own area of interest and expertise, it is possible some students may be happier and/or more successful melding a content area with teaching. Evidence for this can be seen by inter-departmental transfers and the growing number of post-bacs in teaching programs. Just as K-12 teachers suggest career opportunities associated with different content areas to their students, college faculty need to do the same. [Other studies have shown that this practice is often a factor in college students deciding to - or not to- pursue a graduate degree in math or science (Alden & Seiferth, 1981; Button & Brown, 1980; Strauss, 1978).]

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CONSIDERATION OF AN ALTERNATIVE DISSERTATION FORMAT

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The dissertation has been the "rite of passage" among graduate students in America since the doctoral degree has been awarded. It is considered the culmination of the Ph.D. program and provides tangible evidence of one's ability to function at a high academic level. However, as the number of doctorates annually awarded in the United States continues to rise, the dissertation process is being increasingly examined (Duke & Beck, 1999; Isaac, Quinlan, & Walker, 1992; Krathwohl, 1994; Monaghan, 1989). There is much support among faculty to maintain the dissertation in its present traditional form consisting of a lengthy, detailed description of a research project (Isaac et al., 1992). However, there is a need within science education to examine this process and make modifications that will more closely address the purpose of the dissertation and better prepare students for academic life after receiving their degree (CGS, 1991; Duke & Beck, 1999; Krathwohl, 1994).

The Council of Graduate Schools described two primary purposes of the dissertation: (1) it is a training experience which indicates a candidate is able to complete and communicate a complex research task, and (2) it makes an original contribution to a field of knowledge (CGS, 1990). Isaac et al. (1992), in a study of 596 graduate faculty, found near complete agreement with these two purposes for the dissertation. Furthermore, the study indicated that 85% of those surveyed believed there was no viable alternative to the traditional dissertation. The notable exception came from faculty in the "hard" sciences that believed previously published articles could be used as an alternative to the dissertation.

Faculty within the sciences have accepted published articles as a substitution for the tradition dissertation for quite some time. A student with his name on several published articles is considered to have sufficiently demonstrated research and communication skills as well as made a contribution to a field of knowledge. These articles may be with several authors and may originate from several different research studies. While this is a departure from the traditional dissertation requirement, it may provide difficulties on two issues. First, the length of time it requires to gain acceptance for a manuscript to be published may be excessive. At times the initial review may encompass an entire year. Add revisions and resubmission and there is no guarantee of completing the task of having several published articles within a reasonable amount of time. Second, with multiple authors and several projects comes the difficulty of precisely delineating the student contribution to the project and thus ensuring she has adequately demonstrated her ability as a researcher.

Does the traditional dissertation adequately address the two primary purposes for developing such a document? Is there an alternative to the traditional dissertation or the model used in the sciences that better satisfies the reasons for completing the dissertation and better prepares students for what is expected of them after receiving their Ph.D.?

Traditional Dissertation

A traditional dissertation is described as a 200+ page document separated into chapters including; introduction, literature review, methodology, results, and conclusions (Glatthorn, 1998). It is a unified piece of work with the theme of a particular research project running through it. Dissertations in this form are written for a very limited audience, the candidate's committee. Once completed, the document becomes public, available for anyone to read. However, library shelves are filled with dissertations that have never been opened. People most in need of the research contained in these documents (e.g., teachers, administrators, researchers) lack the time necessary to read the typical dissertation and glean from it that information beneficial to them. Increasingly, this traditional form has come under question in education as failing to adequately accomplish the two primary purposes of the dissertation (Monaghan, 1989; Krathwohl, 1994; Duke & Beck, 1999).

If one purpose of completing a dissertation is for training experience, it can be argued we are not training students for the real world of academe. In fact, Krathwohl (1994) observed that at the very point students are in the best position to receive the training necessary to better prepare them in their new careers, they are being asked to use a writing structure they will probably never use again. The traditional dissertation format requires students to spend months writing at length and in great detail about every aspect of the research. Once the dissertation is completed and students take positions within the academic community, time spent writing must be used to produce manuscripts that are succinct. Only the most salient aspects of methodology, literature, results, and conclusions are included within these products. Furthermore, once in academe, it is desirable to communicate with the practitioners in a given field (e.g., teachers and administrators) as well as write for external funding from sources such as the National Science Foundation. The writing style required of the traditional dissertation does not prepare students for the type of writing necessary for the post-dissertation stage of their careers. Rather, students should be working with their mentors on developing skills they will be using, such as journal article writing and proposal for funding preparation (Krathwohl, 1994). Dissertation committee members are in a unique position to assist future members of their academic community and prepare them with the necessary skills to begin new projects as they start their careers rather than rework lengthy dissertations while busy getting accustomed to their roles as faculty members. Much dissertation research never gets published since many students have lost the motivation to examine the same work another time. Many students see the dissertation process as more of a hurdle to pass over on the way to a degree instead of a process of contributing to a field of knowledge and communicating their findings to a wide audience.

Purposes for the dissertations outlined by the CGS are closely linked. That is, communicating a complex research task and contributing to a field of knowledge. With these requirements, a pertinent question becomes, "Communicate to whom?" Frequently this communication is simply to the few committee members and not to the wider audience to which the research might be useful. Few researchers, teachers or administrators to which the research may be of use read the lengthy dissertations archived on university library shelves. Without this communication to wider audiences, the test of authenticity of the research is in question (Halstead, 1988 cited in Duke, & Beck, 1999). As a result, this also brings into question the degree of contribution to a field of knowledge. The wider the audience, the greater the possibility of making a contribution to the field of knowledge within a particular area of study.

The traditional dissertation format is deeply engrained within the education culture. However, there may be a format for the dissertation that better addresses the requirements of a doctoral committee and prepares the student for academic life after the degree.

Alternative Format

An alternative style to the traditional dissertation suggested here is the journal-ready format. In this style, students write a series of manuscripts ready to be submitted for publication following the oral defense. That is, the body of the dissertation takes the form of a combination of research article(s) and practitioner article(s). The appendix may contain further evidence, as the committee deems necessary, of a student's detailed literature search or project design.

Journal-ready dissertations address the challenges associated with the limited readership of traditional dissertations. Rather than writing only for the dissertation committee, the product of a journal-ready dissertation is disseminated to a much wider audience that might include researchers as well as teacher practitioners. Communicating results to a wide audience supports the idea that the dissertation represents a legitimate piece of research. Furthermore, this type of dissertation provides the student with writing and publication skills necessary in their careers.

An additional advantage to this alternative form of the dissertation is that it requires students to examine the outcome of research from differing perspectives within the study. In a typical situation, a study will result in manuscripts being written for both research and practitioner journals. Communicating important findings to both audiences is important, especially since researchers are often criticized for failing to communicate with practitioners. This skill could be practiced and nurtured under the leadership of skilled doctoral committee members through the use of journal-ready dissertations.

The journal-ready dissertation modifies the beneficial aspects of the traditional dissertation and the published article alternative of the sciences. Completing this type of dissertation requires students to prepare manuscripts ready to be submitted for publication but does not restrict awarding the doctoral degree on the condition of their acceptance or publication. The manuscripts developed should reflect pertinent content targeted to the research and practitioner communities. Most importantly, the journal-ready dissertation prepares students for the type of research/scholarship that will be expected of them after they receive the Ph.D. degree.

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THE NATURE OF SCIENCE IN DECISION-MAKING: LEAD ROLE, SUPPORTING CHARACTER, OR OUT OF THE PICTURE?

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Recently, the nature of science has enjoyed renewed attention in science education circles as a primary component of scientific literacy (American Association for the Advancement of Science, 1989, 1993; Bybee, 1997; National Research Council, 1996; National Science Teachers Association, 1982). These documents mandate that teachers of science from kindergarten to graduate school should not only teach in a manner consistent with current views of the scientific enterprise, but should purposively instruct students in specific aspects of the nature of science. This amounts to a huge and uncertain undertaking, since research has shown that, for the most part, few students or teachers are able to articulate adequate understandings of this elusive construct (Duschl, 1990; Lederman, 1992, among others).

From an educational perspective, most agree that educating children to simply recall scientific facts, laws, and theories is not enough. Rather, teachers and science educators want students to know why scientific knowledge and ideas have merit and may be trusted. For example, Munby (1982) promoted science instruction that fosters "intellectual independence" and provides students with "all the resources necessary for judging the truth of knowledge independently of other people" (p. 31). Norris (1992) extended this argument to the "rational trust" of experts when firsthand evidence is impractical. These issues attain practical significance for individuals deciding whether to accept the advice or opinion of scientific "experts" and how to respond to public issues related to science and technology. Thus, public understanding of the nature of science is considered a critical component of democracy, in which people must make decisions on science and technology based issues.

Reform documents agree that, in order for these changes to come about, less emphasis should be placed on teaching science content and more emphasis placed on broad, overarching themes, including scientific inquiry and the nature of science. The nature of science, also known as epistemology of science, or science as a way of knowing, refers to the values and assumptions inherent to scientific knowledge (Spector & Lederman, 1990). These values and assumptions include, but are not limited to, parsimony, tentativeness, subjectivity, and creativity.

Recent commentary has linked nature of science instruction to the ultimate goal of scientific literacy: to improve citizens' abilities to make reasoned decisions in a world increasingly impacted by the processes and products of science (Carey & Smith, 1993; Collins & Shapin, 1986; Cotham & Smith, 1981; Driver, Leach, Millar, & Scott, 1996; Kuhn, Amsel, & O'Loughlin, 1989; Lederman, 1983; Millar & Wynne, 1988). By knowing the characteristics of scientific knowledge and the way it is constructed, the argument proceeds, citizens will be better able to recognize pseudoscientific claims, distinguish good science from bad, and apply scientific knowledge to their everyday lives. Driver, et al. (1996) labeled this the "democratic argument" for nature of science instruction:

> The democratic argument for promoting public understanding of science focuses on the understandings needed to participate in the debates surrounding [science and technologically based] issues and in the decision-making process itself...an understanding of the issues requires not just knowledge of science content, but also an understanding of the nature of science and scientific knowledge. (p.18)

Given the importance science educators have placed on the ultimate outcome of nature of science instruction and scientific literacy, it is disconcerting to realize that little research exists delineating the role of the nature of science in decision making. If preservice teachers are learning this rationale for teaching the nature of science, there should be some empirical evidence that the desired outcomes will be achieved.

Research exploring decision making and the formation of moral judgments on science and technology based issues has found that individuals base decisions on a variety of factors. Zeidler and Schafer (1984) suggested that comprehension of science, positive attitudes, and a strong commitment toward a particular issue were all positively related to the level of moral reasoning used to make social judgments. Fleming (1986a) found that adolescents primarily viewed science and technology based issues in ways that stressed the social aspects of the issue. Students who used nonsocial cognition focused on their perceptions of scientists and the institution of science when analyzing and discussing science and technology based issues (Fleming, 1986b). The single study that directly addressed the role of nature of science conceptions in decision making found that students did not base decisions about their daily conduct on their understandings of the tentative nature of scientific knowledge (Lederman & O'Malley, 1990).

Piaget (1972) and Iozzi (1978) theorized that individuals tend to reason at more sophisticated levels in areas which they have more knowledge. If the nature of science is related to decision making on science and technology based issues, as so many think it is, then it follows that those who understand the nature of science should reason differently on these issues than those who do not.

The purposes of this investigation were to assess the influence of people's understanding of the nature of science on their decision making regarding science and technology based issues and to delineate the factors and reasoning people use when making these types of decisions. The research questions guiding the investigation were

1. What is the relationship, if any, between understandings of the nature of science and decisions regarding science and technology based issues?

2. What is the relationship, if any, between understandings of the nature of science and the factors used to reach decisions on science and technology based issues?

3. What is the relationship, if any, between understandings of the nature of science and the reasoning used to reach decisions on science and technology based issues?

Method

Participants

During the fall of 1998, initial inquiries to attract individuals willing to participate in the investigation were sent via e-mail to university professors and research scientists across the United States. From this initial query, 21 participants agreed to participate in the investigation. In order to assess the impact of divergent views of the nature of science on decision making, these participants were purposively selected to create two groups of adults most likely to possess disparate conceptions of the nature of science.

The first group consisted of 10 university professors and research scientists whose education and research provided ample opportunities for them to reflect on the nature of science (i.e., science educators, science philosophers, and research scientists). These individuals were selected because they were highly likely to possess desired understandings of the nature of science and, thus, provide a "best case" scenario for the nature of science to impact their decision making. The second group consisted of 11 university professors, who, while possessing equivalent amounts of education, were unlikely to have spent much time contemplating the nature of science (i.e., historians, English professors, and business professors). While this purposive selection increased the likelihood of obtaining two groups possessing divergent views of the nature of science, it did not assure this outcome. Therefore, the final group assignments were based on formal assessment of each individual's understandings of the nature of science as described in the next section.

Procedures

Each of the 21 participants were administered two questionnaires, the first designed to gather information about their decision making, and the second to assess their conceptions of the nature of science. Each participant's vita was also collected to provide biographical and academic background data. Following the return of each completed questionnaire, participants were individually interviewed via phone. A total of 42 interviews were conducted, each lasting approximately 45 minutes.

Instruments

Open-ended questionnaires in conjunction with follow-up interviews were used to assess participants' decision making and their conceptions of the nature of science. Such instrumentation was employed to mitigate concerns inherent to the use of standardized, forced-choice instruments (Lederman, 1992; Lederman, Wade, & Bell, 1998).

The Decision Making Questionnaire (DMQ). A panel of experts consisting of four science educators and two research scientists established the face and content validity of this questionnaire. The DMQ's scenarios and items were modified according to the panel's suggestions for improvement. The final version of this questionnaire contained four different scenarios concerning science and technology issues, including fetal tissue implantation, global warming, the relationship between diet and cancer, and the relationship between cigarette smoking and cancer (see Appendix A). Each scenario was followed by three to five questions designed to elicit "yes" or "no" decisions, and to encourage respondents to explicate the factors and reasoning patterns influencing their decisions. Following this questionnaire, the participants were interviewed to provide opportunities for them to clarify and elaborate on their responses to the DMQ. All interviews were audiotaped, transcribed, and subsequently used in conjunction with their responses to the DMQ to construct summary profiles of the participants' decisions and reasoning patterns.

The Nature of Science Questionnaire (NOSQ). This questionnaire (see Appendix B) consisted of six open-ended items adapted from Lederman and O'Malley (1990) and Abd-El-Khalick, Bell, and Lederman (1998). As with the DMQ, the advice of six experts was used to enhance the face and content validity of the instrument. The NOSQ focused on several aspects of the nature of science believed to be relevant to K-12 students and their subsequent participation in decision making as adults in a democratic society (Lederman & Abd-El-Khalick, 1998; Smith et al., 1997). These aspects included tentativeness, empirical basis, subjectivity, creativity, observation versus inference, the role of social and cultural contexts in science, and the functions and relationships among theories, hypotheses, and laws. In order to provide in-depth assessment of the participants' understandings of these aspects of the NOS, individual items asked participants to justify their answers and to support them with relevant examples.

Semistructured interviews were conducted following the administration of the NOSQ, giving participants the opportunity to clarify and elaborate on their answers. Individual profiles of their views of the nature of science were constructed from each participant's responses to the NOSQ and follow-up interview. These profiles were subsequently used to group participants according to their understandings of the nature of science. The 9 participants whose understandings were most consistent with current conceptions (as delineated in philosophy of science literature and science education reform documents) were assigned to Group A. The 9 participants whose understandings were largely inconsistent with current conceptions were assigned to Group B. The 3 participants whose views were mixed and did not clearly fall within either category were dropped from consideration to create a greater distinction between the two groups. Table 1 provides a summary of the academic backgrounds of the participants assigned to both groups.

Data Analysis

Once these group assignments were made, participants' individual DMQ responses were used in conjunction with the corresponding follow-up interview transcripts to construct profiles of each group's decision making. These profiles included total "yes," "no," and "undecided" responses to the DMQ items, lists of factors participants said influenced their decisions, and general reasoning patterns. Each group's profile was then searched for patterns and categories, which were checked against the data and modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce the data. Finally, the research questions were answered by comparing the decision making profiles of Group A and Group B.

Results

Comparison of Group A and Group B Decisions

Participants' "yes" and "no" responses to the 15 DMQ items were tallied for each group and summed separately for each individual DMQ item and the total DMQ. A few DMQ responses were unclear or the respondents were unwilling to commit to a decision for a particular question. These responses were categorized as "undecided."

Table 1
Description of Study Participants

	No. in Group A	No. in Group B
Field in which doctoral degree earned	Science education (4) Education (2) History of science (1) Forest science (1) Conceptual foundations of science (1)	Nuclear engineering (1) Mechanical engineering (1) Special education (1) English (1) Philosophy/history (2) Intercultural studies (1) Soil chemistry (1) Near Eastern studies (1)
Earned bachelor and/or masters degree in a science discipline	9 (biology, zoology, physical science, chemistry)	3 (soil chemistry, nuclear engineering, mechanical engineering)
Place of employment	University: School of Education (6) History dept. (1) Philosophy dept. (1) Forest science dept. (1)	University: School of Education (1) English dept. (1) School of Religion (1) History dept. (2) Information Management dept. (1) Engineering dept. (2) US Environmental Protection Agency (1)

Listed presentations, publications or courses taught on the nature, history or philosophy of science	9	0

Table 2 illustrates a comparison of the Group A and Group B decisions for each question on the DMQ. It is clear that there was little difference in the two groups' overall decisions, despite their disparate views of the nature of science. None of the responses to individual questions, whether "yes," "no," or "undecided," differed between Group A and Group B by more than two. Furthermore, 93% of responses differed by one or less, and 29% did not differ at all. As the comparison of the total number of responses at the bottom of Table 2 indicates, the small differences between Group A and Group B responses to the DMQ could largely be attributed to three additional "undecided" decisions of the Group A participants

Comparison of the Factors that Influenced Group A and Group B Decisions

Group A and B responses to the DMQ were also used to generate a list of the factors that participants said had influenced their decisions. To encourage the listing of such factors, the questions following each of the four scenarios instructed respondents to list the reasons for their decisions. The resulting overall lists of factors generated from the responses of the two groups were used to determine (a) the relative influence of the nature of science in reaching these decisions, and (b) whether there were any differences in the kinds of factors listed between the two groups.

The first step in the analysis of factors was to examine each participant's answers to individual DMQ items for references to factors influencing their decisions. Identified factors were

Table 2
Comparison of Group A and Group B Responses for Each DMQ Question

		Yes		No		Undecided	
		Group		Group		Group	
	Question	**A**	**B**	**A**	**B**	**A**	**B**
Scenario 1 (Fetal Tissue Implantation)	**1**	8	9	1	0	0	0
	2	7	6	2	3	0	0
	3	5	5	3	4	1	0
	4	5	6	4	3	0	0
	5	8	9	0	0	1	0
Scenario 2 (Global Warming)	**1**	8	7	1	1	0	1
	2	6	5	2	4	1	0
	3	7	8	2	1	0	0
	4	7	8	2	1	0	0
Scenario 3 (Diet/Exercise & Cancer)	**1**	9	7	0	2	0	0
	2	7	8	2	1	0	0
	3	2	1	7	8	0	0
Scenario 4 (Smoking & Cancer)	**1**	0	2	8	7	1	0
	2	8	9	1	0	0	0
	3	8	9	1	0	0	0
Totals	**15**	95 (70%)	99 (73%)	36 (27%)	35 (26%)	4 (3%)	1 (1%)

then listed separately for each group per scenario. In most cases, participants listed multiple factors. Next, the four resulting lists of factors were grouped into common categories, such as the nature of science, moral/ethical issues, pragmatism, and personal choice. In all, eight categories were created for the 26 factors identified in the DMQ responses. Note that the first category for each scenario in Table 3 (Nature of Science) was included because of its relevance to the research questions of this investigation, rather than the frequency with which it was cited. Remaining factors were placed in a second broad category (Other). Under "Other," factors mentioned by 3 or more participants in one of the groups were listed separately. For clarity of presentation, factors cited by only one or two participants in a scenario were grouped under the "Miscellaneous" heading.

Scenario 1: Fetal Tissue Implantation. The first scenario dealt with an experimental procedure involving the use of fetal tissue implantation for the treatment of Parkinson's disease. While this scenario contained a strong ethical/moral component, it also provided opportunities for respondents to comment on a variety of nature of science issues, including the subjective nature of whether the fetus is alive, the ways in which science can inform ethical dilemmas, and whether the treatment needed to be proven as effective before participants were willing to recommend it.

The data in Table 3 clearly indicate that the nature of science was not a major contributing factor in the Scenario 1 decisions reached by the members of either Group A or Group B. None of the Group A or Group B participants directly referred to any of characteristics of scientific knowledge in their discussions of how they had reached their decisions. In fact, the only

Table 3

Categories of Decision Making Factors by Scenario

Group A Factors	No. of Respondents	Group B Factors	No. of Respondents
Scenario 1 – Fetal Tissue Implantation			
Nature of science*	0	Nature of science*	0
Other		Other	
Moral/ethical issues	9	Moral/ethical issues	9
Values	9	Values	7
Social/political issues	5	Social/political issues	2
Support of Science	3	Support of Science	1
Miscellaneous	5	Miscellaneous	1
Scenario 2 – Global Warming and Green House Gas Emissions			
Nature of science*	4	Nature of science*	3
Other		Other	
Social/political issues	7	Social/political issues	8
Pragmatism	5	Pragmatism	3
Personal issues/values	6	Personal issues/values	1
Personal philosophy	4	Personal philosophy	5
Economics (cost/benefit)	2	Economics (cost/benefit)	6
Miscellaneous	1	Miscellaneous	2
Scenario 3 – Diet, Exercise, and Cancer			
Nature of science*	5	Nature of science*	2
Other		Other	
Values	9	Values	9
Moderation	4	Moderation	5
Miscellaneous	4	Miscellaneous	3
Scenario 4 – Cigarette Smoking and Cancer			
Nature of science*	3	Nature of science*	1
Other		Other	
Values	9	Values	9
Pragmatism	7	Pragmatism	3
Miscellaneous	5	Miscellaneous	7

*The majority of the "Nature of science" factors consist of superficial references to evidence.

participant who referred to science at all indicated that it was not appropriate for answering the principle questions of the scenario:

> On a final note, just like science alone cannot and should not provide society with a definitive answer regarding when human life begins; it cannot and should not alone decide if and how fetal tissue should be donated. (A5, DMQ)

Noticeably absent from the participants' responses were any references to scientific evidence or the subjective nature of the definition of life. Furthermore, none of the participants indicated that the experimental nature of the treatment influenced their decisions when explicitly asked during the follow-up interviews.

The vast majority of factors identified in Group A and Group B responses to Scenario 1 items fell into the "Other" category. These responses focused on personal values and the social/ethical components of the issue:

> The desire to stay alive and the desire to assist a family member in staying alive is strong and in itself justified if that chance of a cure doesn't negatively impact anyone else in a significant fashion...I can't see any ethical reason why such a treatment regime would not be permitted or even recommended. (A2, DMQ)

> I believe the right to an abortion (before the fetus becomes human) should not be restricted by law…I believe that this group of cells is part of the woman's body and should be treated accordingly. (B8, DMQ)

> If society (and by extension, the legal and medical professions) continues to view a fetus as part of a woman's body, then like organs, donors should be able to request donation of fetal tissue to specific people. (A5, DMQ)

Scenario 2: Global Warming and Green House Gas Emissions. The second DMQ scenario dealt with the connection between greenhouse gas emissions and global warming. The questions following the scenario asked respondents to make decisions having both personal and public impacts, such as whether they would be willing to pay for technology to reduce automobile pollution and whether the US should adopt binding limits on greenhouse gas emissions. The lack of consensus among scientists regarding the reality and potential impact of global warming provided an opportunity for respondents to discuss aspects of the nature of science, including tentativeness and subjectivity, as influencing their decisions.

Categories of the self-reported factors influencing the respondents' decisions in the second scenario are listed in Table 3. Less than half of the participants' in both groups cited factors that may be interpreted to reflect their views of the nature of science. Only 7 of the 21 participants mentioned the use of scientific evidence in their decision making. In general, Group A respondents tended to focus on the inconclusive nature of the evidence.

> I recognize that research on the relationship between gas emissions and global warming is equivocal: The scientific community has yet to reach consensus on this issue. (A5, DMQ)

> Uncertainties about the potential of greenhouse gases to alter climate are still substantial, though a wise reading would indicate a likely connection. (A9, DMQ)

In contrast to these responses, two of the Group B participants referred to the *certainty* of scientific knowledge as a factor in their decisions.

> This is potentially the greatest issue we face, and I discount all propaganda from the energy industries that this is as yet unproven. (B2, DMQ)
> No, the US should not agree to legally binding limits until research conclusively shows that the global warming phenomenon is real. (B9, DMQ)

A third Group B participant seemed to hold a belief more in line with currently accepted views of the tentative nature of science:

> Yes, I think that the risk of global warming is real. Even if actual global warming cannot be scientifically determined, this is not a gamble we should make. (B7, DMQ)

While there appear to be differences in the ways some Group A and Group B participants viewed the certainty of the evidence for global warming, it is important to note that the majority did not mention scientific evidence at all. As is shown in Table 3, social/political issues and personal philosophy—even pragmatism—were reported by the participants much more frequently as factors in their decision making. The most frequently cited factors were also cited about equally between the two groups, although economics was mentioned more often in Group B. Miscellaneous factors included long-term consequences and morals/ethics.

Scenario 3: Diet, Exercise, and Cancer. The third DMQ scenario dealt with the possible links between diet, exercise, and cancer. The three questions following the scenario asked how the participants' knowledge of the benefits a particular dietary program and exercise had impacted their lives and whether they would support legislation prohibiting the sale of certain foods associated with cancer. As with the previous scenarios, these questions were designed to give the participants opportunities to describe factors that influence their personal choices when the scientific evidence is equivocal.

Factors related to the nature of science were cited more frequently in this scenario than in the previous two (Table 3). However, it should be noted that the majority of the factors listed in the nature of science category consisted of rather superficial references to "scientific evidence" or "data." Two Group A responses reflected more in-depth understandings by focusing the weight of the evidence and the lack of consensus among scientists:

> In addition, researchers (and governments!) often draw conclusions that are not based on strong evidence (indeed, many epidemiological studies cannot, by their very nature, produce strong evidence) and I'd hate to proliferate science based on weak evidence (or on evidence of weak impacts). (A9, DMQ)

> While I find current studies on diet and cancer compelling enough to change my own habits, I am uncertain there is enough scientific research or consensus among members of the scientific community to support legislation on foods associated with cancer. (A5, DMQ)

However, it is important to note that evidence alone did not determine Group A's decisions.

> I also recognize that science can and should be only one of many voices in deciding how and what legislation is passed: I wonder if current scientific evidence would outweigh economic losses and public outcry. (A5, DMQ)

The two participants in Group B who mentioned science (both in response to Item 3 about legislation) viewed science as being inadequate to produce a clear-cut answer.

> I must admit, however, that given the scientific flip-flopping over the years about the merits and demerits of certain foods, I am somewhat skeptical about the research results. (B1, DMQ)

> No—this is an imperfect science at best. We don't know exactly how diet, exercise, heredity, and stress interact to cause cancer, so it is premature to focus on one factor. (B6, DMQ)

Viewing the progression of scientific knowledge as flip-flopping or as imperfect is consistent with the more absolute views of scientific knowledge expressed by Group B on the NOSQ. What is surprising is that more Group B participants did not respond this way.

Values, including factors such as convenience, self-image, and especially personal benefit, were cited by every participant in this scenario. A small but roughly equal number of participants in both groups referred to moderation in regard to diet ("I can't believe all of these 'bad' things are necessarily bad if taken in moderation" B7, DMQ). The miscellaneous category included factors such as societal rights and social issues, economics, and morals/ethics. All factors were mentioned with similar frequency in both groups.

In both groups, even when they were convinced of the benefits of proper diet and exercise, participants admitted to having trouble acting on their convictions.

> I like to think that as a type A guy I am always on the go, but in all honesty I do not have a regular exercise plan. This is one area where my knowledge of the facts say one thing and my actions do not conform to what I know to be true. (A2, DMQ)

> Yes, I try to eat broccoli and fish more often and red meat less often. I am not as good about this as I would like, due to laziness, but I have tried to improve. (B8, DMQ)

When pressed in the interview about what kind of evidence would convince them to change their diet and exercise habits, many participants indicated that the issue for them was not weak science, but weak willpower:

> I don't know if science could do any more at this point. I think it's a matter of saying, "Okay, this is something that needs incorporated in my own personal lifestyle. I need to be exercising and eating right." It has to be more of a personal concern, like a family thing, you know, "We're worried about you and your cholesterol. We want you around for a while." It has to be a more personal level to lead to that kind of motivation. (B9, DMQ)

> I think the evidence that regular exercise is beneficial is pretty unarguable, as I understand it from a wide range of features, such as cardiovascular health, happiness with what level of activity you're having, and ability to do the things you enjoy — all those things are persuasive that exercise regularly is a good idea. And the reason I don't is just a little irrational, I suppose, but not having found any regular exercise that is enjoyable, has made it easy to be a little slothful and not do the optimal thing. (A9, DMQ)

Scenario 4: Cigarette Smoking and Cancer. The last DMQ scenario dealt with the possible links between cigarette smoking and cancer in humans. The questions following the scenario asked about prohibiting smoking, limiting the availability of cigarettes for minors, and banning smoking in public buildings.

Three Group A participants and one Group B participant mentioned the existence of scientific evidence when justifying their decisions (Table 3). Only one of these went beyond a simple reference to unspecified, general evidence. This Group A participant described using consensus among scientists as a factor in decision making.

> If one were to use only scientific criteria in deciding whether or not to render smoking illegal, there appears enough rigorous research and consensus within the scientific community to support such anti-smoking legislation. Proponents of

> tobacco who claim "lack of proof" distort the purposes, language, and practices of science to further their own agenda. Of course, legislators can and should not look solely to science to make this decision; they must consider economic issues, social norms, and lessons of history (to name just a few). (A5, DMQ)

For the Other category in this scenario, values such as personal choice and personal convenience were cited most frequently in both groups. Five participants in Group A and 8 in Group B expressed the importance of protecting minors from cigarettes, even though it meant limiting their freedom. Pragmatism ("it wouldn't work") was cited as a factor about twice as often in Group A, mainly in response to Item 1 about making cigarette smoking illegal. In the miscellaneous category, a few participants in both groups cited social and economic issues. Two participants in Group B cited moral/ethical factors.

Overall, the lists of factors generated from the Group A and Group B responses to the DMQ indicated that the nature of science played, at best, a minor role in participants' decision making on the science and technology based issues. In the relatively few times the participants referred to factors related to the nature of science, their responses did not go beyond simple acknowledgement of the existence of scientific evidence. Other factors, including social/political issues, ethical considerations, and personal values, were cited both more frequently and elaborately.

Comparison of Group A and Group B Reasoning

Both the DMQ and the follow-up interviews were intended to provide opportunities for participants to describe and elaborate on their reasoning on science and technology based issues. The interviews, in particular, were designed to elicit the participants' reasoning related to their decision making. In this regard, participants were asked two or three questions emphasizing the equivocal nature of the science related to one or more of the scenarios.

For example, in Scenario 1, participants were asked how the experimental nature of the fetal tissue treatment affected their decisions. In Scenario 2, participants were presented with an alternative explanation for global warming (land-form alterations), based on the most current science. In view of this conflicting evidence, participants were asked how they could make decisions about regulating carbon emissions. In Scenario 3, the researcher asked participants how they could make decisions about nutrition when researchers, based on scientific evidence, have altered their recommendations, as in the case of the inclusion of Omega-3 fatty acids in the diet. The Scenario 4 probing question asked whether participants would change their decisions based on some scientists' assertions that the links between tobacco and cancer have never been proven. These probing questions were intended to elicit participants' reasoning on controversial science and technology based issues and prompt the participants to illuminate how their views of the nature of science impacted their reasoning.

The DMQ responses and interview transcripts were searched for participants' reasoning patterns as they responded to the probing questions. Not all participants clearly elucidated their reasoning, but most provided multiple decision making strategies that could be classified. A total of six different reasoning patterns were identified and were remarkably similar between the two groups (Table 4). This similarity was consistent with the other findings of this study regarding the participants'decisions and factors they used in reaching these decisions.

Group A General Reasoning. All 9 participants in Group A said they considered the "evidence" when making decisions on science and technology based issues. While they realized scientific evidence on such issues is often equivocal or incomplete, they found it useful in informing their decisions and often spoke of using the "best available evidence."

Table 4

Group A and B Decision Making Strategies

Strategy	No. of Group A Participants	No. of Group B Participants
Consider the Evidence	9	9
Conservatism	4	5
Risk Analysis	4	1
Cost/Benefit Analysis	3	2
Values-Based	3	3

Respondents also referred to historical evidence in the first item of Scenario 4 of the DMQ to argue that banning cigarette smoking would not work. They often compared banning cigarette smoking to the prohibition of alcohol in the 1920s. These arguments emphasized the similarities between banning alcohol consumption and banning cigarette smoking, as well as the negative outcomes of prohibition:

> I do not believe such legislation should be passed. Even if smoking could be made illegal, smokers would find ways of getting tobacco. I imagine a situation similar to Prohibition would arise. (A6, DMQ)

Although all referred to considering evidence, none of them claimed to use evidence alone in their decision making. Four expressed a personal philosophy related to conservatism. For these participants, if the evidence did not provide a clear-cut answer, they decided the issue by maintaining the *status quo*, deciding in favor of safety, or using moderation:

> Researcher: And what do you do when you look at the empirical evidence and scientists are saying that greenhouse gas emissions are causing global warming and others saying that either it isn't happening, or if it is happening, we don't know whether it's the greenhouse gases that are causing it?
>
> Subject: Take two scientists and call me in the morning. I want to hear from more people. I think before you ask an entire nation to change their diet, for instance, you need to be pretty darn sure that it is a

reasonable way to proceed. So, as far as I'm concerned, we just need more data.

Researcher: And if you're asked to make a decision before you have "enough data?" What do you do?

Subject: *Status quo*. My general rationale about these types of initiatives, for instance, is to maintain the *status quo*, unless there is clear evidence that one should alter the *status quo*. (A2, DMQ-interview)

Four participants cited risk analysis as a strategy for decision making when the evidence was equivocal:

> For example, living in a cave would greatly reduce my chances of being killed by a meteorite. The risk is real, the outcome severe—but the probability is incredibly slight. Similarly, if I aim to reduce my risk of cancer by 20%, I'd need to know the actual probability of cancer. If 1 in 20 people get cancer, then a 20% reduction in risk would be worth a large sacrifice. If 1 in 2000 get this type of cancer, then less sacrifice would be rational. (A9, DMQ)

A similar reasoning pattern involved making a cost/benefit analysis, including the costs of being wrong, additional benefits whether wrong or right, and/or a balance of evidence and values.

Three participants specifically said they tempered the scientific evidence with their values or emotions on the issue. As with the written responses to the DMQ, values or emotions weighed heavily in their verbal responses to the interview questions:

> I think scientific evidence in any new area is going to be equivocal. Because that's just the way science is done. Look at the history of science. There's always lots of ideas brought forth when there's a new area under investigation. It takes a while for scientists to reach consensus on what are the one or two views they're going to have on that topic. So, I think that as a citizen, you take the scientific information, but then you also have to make decisions based on values and societal, cultural, and personal goals. And that's true of any sort of everyday decision that relates to science and technology. I don't think anybody takes scientific information, whether it's equivocal or unequivocal and incorporates it whole clause into their everyday experience. (A5, DMQ-interview)

Group B General Reasoning. Like their Group A counterparts, all of the Group B participants claimed to consider evidence when making decisions on science and technology based issues. There were differences, however, in the ways some viewed the evidence. While the Group A participants viewed the evidence as imperfect and equivocal but still useful, some of the Group B participants looked for long-term consistency and absolute "proof." They were skeptical of science when these could not be provided.

> Researcher: In Question #3 in the second paragraph, you had a really interesting comment. Here you said, "I must admit however that given the scientific flip-flopping over the years about the merits and demerits of certain foods, I am somewhat skeptical about the research results." What do you mean by flip-flopping?
>
> Subject: It seems to me they have gone back and forth on a number of foods. For a considerable amount of time they said caffeine was bad for you, I just read recently that in moderation it can be very good for stimulating blood circulation....Yeah, it's stuff like that; it's the same with wine, eggs, etc. It seems to me in all the fields, that is the one with the most flip-flopping back and forth, what's healthy and what's not healthy. That makes me skeptical. (B1, DMQ-interview)

Otherwise, reasoning patterns were remarkably similar to those of Group A. Five participants said that when the evidence was equivocal, they fell back on a conservative philosophy, acting in favor of safety or using moderation (phrases like "balanced diet" and "variety" came out especially in Scenario 3 on nutrition). One participant, the nuclear scientist, said he used risk analysis, trying to determine what was "most likely to happen." Two looked at costs versus benefits. One reasoned that understating the problem could be catastrophic, while overstating the problem had less significant consequences. The other compared impacts on freedom to impacts on health and safety.

Three participants cited values and emotions in their reasoning process, things like a "gut feeling," "common sense," and a "familiar way of life." One participant who was trying a vegetarian diet because he believed it was good for his health admitted that sometimes he deviated for reasons having little to do with scientific evidence:

> I don't know, I'm in a quandary about this. My daughters want to be vegetarians and when they're at home, I generally make vegetarian meals for them. I think that there are reasons for becoming vegetarian, and then, on the other hand, every two to three weeks I'm feeling low on energy, so I go out and buy a steak. (B8, DMQ-interview)

In summary, both Group A and Group B participants used six different categories of reasoning to justify their decisions on the NOSQ. While all the participants referred to the use of evidence in their reasoning, only a few specifically spoke of aspects of evidence related to the nature of science. The majority of participants in both groups found evidence useful for making decisions even though the evidence was not absolute. This finding was consistent with Group A's responses to the NOSQ, but inconsistent with Group B's more absolute responses. Even though all participants cited evidence as a consideration in their decision making, evidence was not the sole influence, nor did it appear to be the primary influence for any of the participants. Consistent with the decision factors the participants had listed on the DMQ, their reasoning patterns focused on personal values and the social and political perspectives of the issues.

Discussion and Implications

The purposes of this investigation were to assess the influence of understandings of the nature of science on decision making regarding science and technology based issues and to delineate the factors and reasoning used when making these types of decisions. To explore this question, the decision making of two groups of college professors and research scientists who held disparate understandings of the nature of science was examined.

This examination found that there were few differences in the factors influencing the two groups' decisions on complex, controversial science and technology based issues. Factors associated with the nature of science played an insignificant role for a minority of the respondents and no clear role for the majority. Other factors, including social/political issues, ethical considerations, and personal values, appeared to dominate the participants' decision making. These factors were in line with the results of previous research on socio-scientific decision making (Fleming, 1986a, 1986b; Zeidler & Shafer, 1984).

The processes the two groups used to reach their decisions were generally similar, although not always consistent with their views of the nature of science. However, in both groups an understanding of the nature of science regarding evidence emerged as only one of several reasoning patterns. Once again, it appeared to play only a minor role in influencing decisions.

Finally and perhaps most important, the actual decisions reached by the members of the two groups were not substantially different. Therefore, even if the minor differences in reasoning were viewed as significant, the differences have little practical significance because the two groups' decisions were largely equivalent. The participants had to have based their decisions on factors other than their understandings of the nature of science to come to the same conclusions.

Surprisingly most of the Group B participants' reasoning was remarkably similar to that of Group A in that they did not need absolute scientific evidence before they could make decisions on science and technology based issues. This finding contrasts with previous studies in which those with less sophisticated understandings of the nature of science required more absolute knowledge from science before they could make personal and public decisions

(Lederman & O'Malley, 1990; Miller & Wynne, 1988). But why was Group B respondents' reasoning on these scientific and technology based issues less absolute than their views of the nature of science?

One possibility is that the decisions reflected the participants' general epistemologies of knowledge, rather their views of science epistemology. Group B participants consisted of 3 scientists and 6 academicians in the humanities. When responding to the science-specific items of the NOSQ, which required metacognition about the construction of scientific knowledge, participants' absolute views of science were evident. But, when responding to the issues of the DMQ, which had a social component, the participants found themselves on more familiar ground and were able to apply their general epistemologies of knowledge (as described by Schommer & Walker, 1995). Future research should focus on the relationship between general epistemologies of knowledge and decision making to see if this relationship is supported.

The participants' high level of intellectual development is another possibility for the inconsistency between the majority of Group B participants' views of the absolute nature of scientific knowledge and their acceptance of tentative scientific evidence in making decisions. Perry (1970) described intellectual development in college students as progressing through four distinct stages. Each stage is characterized by different views of knowledge, starting with a positivist stance (Dualism) and culminating in a view of knowledge as constructed, contextual, and tentative (Commitment to Relativism). It is possible that while many Group B participants held absolute views of the nature of science, a topic that was relatively unfamiliar to them, their use of knowledge in general was mediated by the relativistic views associated with their high levels of intellectual development. If a connection between intellectual development and decision making is established by subsequent studies, then elementary and secondary school students may not be developmentally ready for the type of nature of science instruction that this study implies. Students who are not ready for relativistic type thinking (Perry, 1970) may become frustrated or cynical when exposed to instruction about the tentative nature of scientific knowledge. Such instruction may do more harm than good (Winchester, 1993).

There is a more straightforward explanation for the apparent discrepancy between the Group B participants' more absolute views of the nature of science and their willingness to use equivocal scientific evidence in their decision making. It may be that their decision making was primarily impacted by factors other than the nature of science, such as values and ethics. This conclusion is not only supported by the analyses of the two groups' decisions, factors influencing decisions, and reasoning patterns, but is consistent with prior research on decision making (Fleming, 1981a, 1981b). Group A and Group B participants commonly spoke of using values to help in their decision making on the scientific and technology based issues of the DMQ. For the Group A participants, values were used in conjunction with their understandings of the relevant science:

> So, I think that as a citizen, you take the scientific information, but then you also have to make decisions based on values and societal, cultural, and personal goals. And that's true of any sort of everyday decision that relates to science and technology. I don't think anybody takes scientific information, whether it's equivocal or unequivocal and incorporates it whole clause into their everyday experience. (A5, NOSQ-interview)

The Group B participants, most of who knew little science content, tended to rely on values *instead of* the science:

> Researcher: How does this equivocal nature of the information you get from nutritionists and doctors affect your decision making?

Subject: I think I probably just kind of roll with the punches and use my good common sense. I'm sure that eating a lot of fat red meats and stuff like that is not good, but that doesn't mean I don't go out and have a Whopper once a month, you know… I think I have a reasonably balanced diet, so I kind of don't worry about it one way or another. (B2, NOSQ-interview)

Either way, it was evident that personal values were much more prevalent in the decision making of the members of the two groups than their understandings of the nature of science. That being the case, moral development may be an important consideration when assessing decision making strategies on science and technology based issues. This conclusion is consistent with prior research focusing on college students' responses to socio-scientific dilemmas (Zeidler & Schafer, 1984) and suggests the need for research that explores the relationship between decision making and moral development.

The results of this study alone should generalizable to the entire population of adult decision makers. The investigation was based upon a stratified, nonrandom sampling of a nonrepresentative segment of the voting adults. While the sampling and methodology allowed for a best-case test of the assumption that understandings of the nature of science significantly impact decision making on science and technology based issues, the results of the investigation are not generalizable to the public as a whole. Future work should seek to increase the generalizability of the research reported here by sampling populations more representative of the voting public.

Should the results of subsequent investigations support the generalizability of the negative results of the present study, the question of why teach the nature of science becomes even more critical. Answering this question provides implications for science education and direction for future research. For example, some have argued that nature of science instruction can facilitate the learning of other science content (see Driver, et al., 1996). Typically, students experience a wide range of direct instruction and conformational, cookbook-style laboratory experiences in their science instruction. It is not surprising that in such an environment, students often develop the misconception that scientific knowledge is portrayed as the result of steady and unproblematic accumulation of confirmed hypotheses (Carey & Smith, 1993). This view is essentially inductivist or empiricist and overemphasizes the role of data in the construction of scientific knowledge (Hodson, 1985, 1988; Nadeau & Desautels, 1984; Strike & Posner, 1985).

However, in the actual practice of science, scientific concepts and controversies are almost never decided by data alone (Collings & Pinch, 1996; Kuhn, 1970, Popper, 1988). Without an appreciation of the conjectural nature of scientific knowledge, students may adopt an inefficient, passive learning style, or simply decide that science is not for them (Driver, et al., 1996). Indeed, science educators have argued that learning science content would be enhanced by drawing attention to the similarities between students' conceptual change and the nature of scientific revolutions (Hodson, 1988), and learning and reflecting on the history of the development of scientific knowledge (Solomon, 1991). Previous studies provide initial support for these ideas by suggesting a relationship between views of the nature of science and conceptual understanding in science (Kuhn, et al., 1988; Shapiro, 1989, 1994; Songer & Linn, 1991). Future research should be directed at delineating any relationship between what students know about science and their understandings of science content.

It is possible, perhaps even likely, that results of the suggested empirical studies will not support the assumptions and hopes that many science educators hold for the nature of science. If this is the case, the science education community may be forced to decide between empirical evidence and what it values. In other words, even if the nature of science is not typically used in decision making, the science education community may decide that it *should* be. After all, it appears intuitive that knowledge about science would be helpful in deciding science and technology based issues and dilemmas. Perhaps the public would make better decisions on science and technology based issues if they were taught how to apply current understandings of the nature of science to their decision making. Therefore, explicit instruction on how to use current views of the nature of science in decision making may be warranted. Curricula promoting this kind of instruction should emphasize the relevance of the nature of science to students' everyday experiences and decisions, as well as provide opportunities for students to use their understandings to make decisions on controversial science and technology based issues.

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Appendix A

Decision Making Questionnaire

Last six digits of your social security number: xxx - ____ - _______

Instructions

Answer the following questions, using the back of the page if you need more space. Please note that there are no "right" or "wrong" answers to these questions. I am simply interested in your views on a number of issues about science.

Scenario I

In the past decade, research has opened the doors to fetal tissue transplantation, a procedure that typically involves transferring tissue from an aborted fetus to another human. The procedure could potentially provide therapy for victims of a variety of debilitating diseases, including diabetes, Parkinson's disease and Alzheimer's disease. As in many areas of biotechnology, the development of this technique has outpaced the development of ethical policy. Please read the following scenario and thoughtfully answer the questions that follow.

> Bill and Sally are a happily married couple in their late 30s. They enjoy a comfortable life style and a stable home life with their two teen-aged children. Recently, Sally's elderly father was diagnosed as having Parkinson's disease, a slowly progressive disabling ailment marked by tremor and increasing muscular stiffness. His symptoms are mild but his physician has explained that he will become more and more incapacitated with time.
>
> Close to the time that she learns about her father, Sally reads an article in the local newspaper about a research project being run at a local university. A team of researchers, led by Dr. Harrison, have applied to the federal and state governments for permission to do a study with Parkinson's victims. She visits with Dr. Harrison to learn more about the disease. During the course of their discussions, she finds out that the progression of Parkinson's can be slowed and possibly reversed by implanting fetal brain cells in the brain of the patient.
>
> Two months later Sally is surprised to learn that she has become pregnant. Due to the unexpected nature of the pregnancy, Sally considers aborting the fetus. Furthermore, as her father's condition begins to deteriorate, she and Bill consider some therapeutic options for him. Recalling her discussions with Dr. Harrison, Sally and Bill begin to discuss the option of using tissue from the fetus in her womb to donate the cells to cure her father.

Questions:

1. Given the experimental nature of fetal tissue transplant treatments, are Sally and Bill justified in considering the procedure for her father? Why or why not?

2. If Bill and Sally decide to abort the fetus, should they be allowed to donate the fetal tissue for transplantation? Why or why not?

1. Should Bill and Sally be allowed to designate Sally's father as recipient of the fetal tissue? Why or why not?

2. Should Sally be allowed to have the abortion if her primary reason for wanting it is to provide a source of tissue for transplantation into her father? Why or why not?

3. Should Dr. Harrison be allowed to continue his work on fetal brain tissue transplantation as a treatment for Parkinson's disease? Why or why not?

Scenario II

Today, global climate change is a major environmental issue facing the United States and the international community. According to one side, the prospect of human-induced global warming is a near certainty, and failure to address the problem will have catastrophic ecological consequences. According to the other side, global warming is a hypothesis lacking scientific validation, and reducing greenhouse gas emissions will have serious negative economic consequences.

In 1992, the United States, along with roughly 150 other nations, signed the United Nations Framework Convention on Climate Change (FCCC) at the Earth Summit in Rio de Janeiro. The FCCC was ratified by the US Senate in 1992 and has now been ratified by a total of 166 nations. The ultimate objective of this treaty is to "achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." In line with this objective, the most industrialized nations, including the U.S., agreed to the voluntarily aim of returning their greenhouse gas emissions back to 1990 levels by the year 2000. However, the U.S. and most other industrialized nations are not on course to meet this target. In fact, emissions in the U.S. are projected to be 13 percent higher in the year 2000 than they were in 1990.

Because these voluntary targets have proven inadequate in curbing emissions growth, there is now widespread agreement that legally-binding measures are necessary. The upcoming climate conference in Kyoto, Japan, is based on the premise that the participating nations should agree, for the first time, upon a legally-binding limit on emissions.

Questions:

1. Should the U.S. agree to legally-binding limits on greenhouse gas emissions? Why or why not?

2. Should the U.S. impose special taxes on carbon dioxide emission to encourage energy conservation, even if this increased monthly electricity and heating bills by $25 per month? Why or why not?

3. Would you be willing to pay increased taxes in order to provide funding for research on alternative energy resources, such as solar power and fusion reactors? Why or why not?

4. Should the U.S. reduce automobile emissions by setting higher gas mileage standards, even if this increased the average cost of a new car by $500? Why or why not?

Scenario III

Researchers are just beginning to unravel the role of diet and nutrition in the development of cancer, or carcinogenesis. It is clear that carcinogenesis is a slow process, often taking 10 to 30 years. Diet may play an important role during the initiation of cancer whereby certain foods may serve to increase detoxifying enzymes that help stop the initial stimulation and growth of the cancer cells. At the same time, other nutrients and foods such as fat may serve as promoters for already initiated cancer cells.

Scientists have estimated that diet is responsible for 20 to 40 percent of all cancers, perhaps as high as 70 percent. Diets rich in fruits, vegetables, and fiber have consistently been shown to have a beneficial effect on cancer. On the other hand, heavy consumption of red meats, saturated fats, and salty foods have been linked to a variety of cancers. Other lifestyle factors related to nutrition also appear to be associated with cancer. Obesity has been linked to a variety of cancers, including endometrial, breast, colon, and ovarian. Alcohol consumption has been linked to cancers of the digestive tract and liver. Conversely, several studies have supported the beneficial aspects of physical activity, which may reduce the risk of several types of cancer, including colon, breast, and prostate.

Questions

1. How would you rate your overall awareness of the impact of diet and related factors on the development of cancer?

2. Has your awareness of the benefits of physical activity and a diet rich in fruits and vegetables impacted how you conduct your life? If not, why not? If so, in what way(s)?

3. Do you ever base decisions about what to eat on your understandings of current research into diet and cancer? If not, why not. If so, in what ways?

4. Do you regularly exercise? Why or why not?

5. Would you support increased legislation on foods associated with cancer, including removing high risk foods from the market?

Scenario IV

Many researchers believe that smoking accounts for a large proportion of all cancers and as much as 30 percent of all cancer deaths. Cigarette smoking has specifically been implicated as the cause of cancer of the lung, oral cavity, larynx, esophagus, bladder, kidney, and pancreas. Additionally, the risk of developing cancer is greater for people who smoke more and who start smoking at a younger age. Furthermore, researchers believe that smoking may be the cause of 25 to 30 percent of all heart disease. Exposure to passive tobacco smoke is very likely a significant cause of cancer in nonsmokers. Some scientists believe that the increased risk could be as high as 50 percent. It has been estimated that thousands of people die each year due to exposure to passive cigarette smoke.

Recently, nicotine in cigarette tobacco has been identified as a drug whose addictiveness exceeds that of opium and heroine. In addition to this, documents have come to light that indicate that some tobacco companies have used a variety of methods to increase the amount and potency of nicotine in cigarette tobacco. Finally, it has been shown that many people begin smoking as teenagers, and once started, have a very difficult time quitting.

In contrast to these claims, tobacco companies have consistently asserted that while tobacco may be associated with increased risk for various cancers and heart disease, it has never been *proven* to cause these diseases. Furthermore, to smoke or not is a free choice that should be up to the consumer, not government agencies.

Questions

1. Given the reported dangers of cigarette smoke and its addictiveness, should legislation be passed that would make cigarette smoking illegal? Why or why not?

2. Would you support legislation that makes it more difficult for minors to obtain cigarettes and/or penalizes tobacco companies who target minors in their advertising? Why or why not?

3. Do the alleged dangers of passive cigarette smoke justify banning smoking in public places such as restaurants and bars? Why or why not?

Appendix B

Nature of Science Questionnaire

Last six digits of your social security number: xxx - ____ - _______

Instructions

Answer the following questions, using the back of the page if you need more space. Please note that there are no "right" or "wrong" answers to these questions. I am simply interested in your views of a number of issues about science.

1. After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.

Note: Parentheticals are not part of the questionnaire.

(This question aims to assess understandings of the tentative nature of scientific claims and why these claims change. It is common for respondents to attribute such change solely to the accumulation of new facts and technologies, rather than the inferential nature of scientific theories and/or paradigm shifts. The question also aims to assess respondents' understandings of the role of theories in science as well as the theory-laden nature of scientific observations).

2. Science textbooks often represent the atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?

(This question aims to assess understandings of the role of human inference and creativity in science, the role of models in science, and the notion that scientific models are not copies of reality.)

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

(This question aims to get at a common misconception about the relationship between the products of science. Many respondents believe in a hierarchical relationship between the two whereby theories become laws if and when enough evidence has been accumulated in their favor. Additionally, respondents express many ideas related to their understandings of the nature of science and science process as they attempt to delineate the difference between theories and laws.)

4. How are science and art similar? How are they different?

(This question aims to assess understandings of the role of creativity and imagination in science, the necessity of empirical evidence in generating scientific knowledge, and the cultural and social embeddedness of science.)

5. Scientists perform experiments/investigations when trying to solve problems. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments/investigations? Please explain your answer and provide appropriate examples.

(This question aims to assess respondents' understandings of the role of human creativity and imagination in science. While respondents generally recognize that experimental design involves creativity, they rarely say that creativity is used in data analysis in the sense that scientists are, for instance, "creating" patterns rather than "discovering" them.)

6. In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while others believed that it is shrinking; still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?

(By posing a scientific controversy and stressing the fact that scientists are using the same data but coming up with differing explanations, this question invites respondents to think about factors that affect scientists' work. The factors range from scientists' personal preferences and biases to differing theoretical commitments to social and cultural factors.)

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DESIGNING VIDEO-BASED SCIENCE CONTENT INSTRUCTION FOR ELEMENTARY TEACHERS

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Overview of Project

An enduring challenge in science education has been the design and delivery of science content coursework relevant to the needs of elementary teachers. The challenge is particularly significant in that elementary teachers have a uniquely important role in science education. During the elementary years, teachers introduce children to science as a "subject" in school, to science as profession, and to science as an aspect of our culture (see Selected References).

AETS has collaborated with the Annenberg/CPB Channel operated by Harvard-Smithsonian Center for Astrophysics (referred to as the Center) to produce an eight-hour video series designed to teach science content to elementary teachers. The project was funded by the Annenberg/CPB Math and Science Project. This is the first time the Center has collaborated with an organization to produce a video workshop series.

Through an internal selection process, AETS provided four content guides to work with the Center production staff to research, write, and provide advice for the content and pedagogy in the series. In addition the guides reviewed revised material and suggested print, video, and web-based materials for learning beyond the context of the video programs (see Figure 1).

March 11, 1998
Larry Flick, 1999 president of AETS, and Gordon Lewis, a senior project officer with the Annenberg/CPB Math and Science Project, meet in Washington D.C. to discuss collaboration.

April 6, 1998
Flick sends memo to the Board describes project.

May 31, 1998
At the AETS summer Board meeting in Chicago, Nancy Finkelstein, of the Annenberg Channel operated by the Science Media Group of the Harvard Center for Astrophysics, and Gordon Lewis present plans to produce an 8-hour, elementary science video workshop. This would be the first time that The Channel at collaborated with an entire organization (AETS) and the first workshop series with a science content rather than pedagogical focus.

June 3, 1998
Letter to Finkelstein and Lewis announces Board approval of the collaboration.

August 15, 1998
An announcement and invitation to apply to become a content guide, site facilitator, on-camera presenter, or suggest science content for the series was mailed to all AETS members by Finkelstein at the Center for Astrophysics.

November 16, 1998
Letter of acceptance was sent to four content guides out of eight total applicants.

December 2, 1998
Flick sends memo to content guides initiating the process of considering concepts and format for the workshop series.

January 15, 1999
Finkelstein convenes first meeting of content guides to begin framing the project. Besides the eight, one-hour video tapes, the workshop series will be coordinated with a web site and email list-serve and a print guide.

February 23-24, 1999
Content guides meet with the entire production staff for the project at the Center for Astrophysics in Cambridge, MA. The concept of "Light" is selected for the central theme. The series will be produced as eight, one-hour programs. Title for the series is chosen: Shedding Light on Science.

March 25-31, 1999
Content guides meet individually with Veda Reilly, producer for the series, and Dana Reilly-Black, a Center staff member. Each 2-3 hour meeting focused and fleshed out the content and video components for each workshop.

April-August 1999
Through email and phone communication various components of the series are created, revised, written, rewritten, and rewritten. During this time, Christine Jones, a scientist at the Center, and Anita Greenwood are selected as the on-camera hosts for the series.

September-December 1999
Writing and revision of components continue until final production of the first one-hour program is completed for broadcast in October. Through the early weeks in school Veda Reilly travels to schools in Massachusetts, Michigan, and Oregon to tape activities specially designed for the series implemented with elementary teachers and students.

The series was broadcast over a satellite owned by the Corporation for Public Broadcasting. Several sites around the country used this initial broadcast of the series as the basis for in-service and pre-service programs. "Shedding Light On Science" may be recorded and freely copied.

Figure 1. Project timeline.

Content guides and staff at the Center collaboratively selected the topic of "light" as the content focus with the title: "Shedding Light on Science" (see Figure 2). The series went through twelve months of design and production from December, 1998 to December, 1999. Initial broadcast of the series was from October to December of 1999.

ABOUT THE SERIES: DESCRIPTION AND INFORMATION
Series Overview

Science provides one way of knowing about the mysteries and splendor of our natural world. Science is a unique collaboration between human perceptions and our ability to reason and build ideas. The concept of light is an appropriate starting point for building an understanding of science because it is through the interaction of light, our eyes, and our brain that we collect most of the information we have about the world.

This series uses light as a theme through which to explore topics in physics, chemistry, biology, and Earth and space science. Unlike most science content courses that approach subject matter through one narrow discipline, these workshops show how light is a common thread that runs through many areas of science. The workshops make connections to real world phenomena as they explore the behavior of light, the transformation of energy, and the role of light in plant production of food, weather and the seasons, and more.

What will you actually see? You will visit elementary classrooms where students are investigating light. You will observe teachers in academic settings studying light and its characteristics. Interviews with experts will further illuminate the topics of energy, human vision, and the Sun's effects on ecosystems, climate, and seasons.

The series emphasizes dynamic interaction with the science content through discussion, activities, and application of the ideas to teaching. The videos and supporting materials suggest many fascinating investigations for you and your students. You will be able to respond to questions such as: What is color? Do plants eat? What causes seasons? Where do winds come from? Where do they go? How does the eye see?

Support resources for the series are available in the form of a print guide and a Web site, as well as instructional ideas contained in the video programs. These resources include activities, lesson plans, assessments, links to other content, and strategies for using community resources. An ongoing activity that builds on the concepts presented throughout the series will be conducted across the eight workshops.

The concepts and activities in this series address the AAAS Benchmarks and the NRC National Science Education Standards with special attention to habits of mind and the history and nature of science. The series also serves as a model for teaching science to elementary teachers and, as such, may be beneficial for district inservice workshops. While the concepts and activities have been designed with the elementary teacher in mind, the materials are beneficial for any educator interested in learning science concepts and the nature of science.

Figure 2: Series overview for video tape content series for elementary teachers. This text can be found on The Channel's web site http://www.learner.org/channel/workshops/sheddinglight/.

An extensive web site was created as part of this project. It features interactive components that help develop concepts associated with light. The site contains learning objectives linked to Benchmarks for Scientific Literacy and National Science Education Standards. Additional activities on the site include a "light history" timeline, activities involving the use of cameras, a process for getting connected with a "light buddy" across the country, a light glossary, and highlights that explores content of the video programs in more depth. The URL is: http://www.learner.org/channel/workshops/sheddinglight/.

Factors in Designing the Workshops

Several factors directly influenced the deliberative process in designing the series and associated print and web materials. From the beginning, AETS content guides and staff at the Center considered major issues faced by all institutions in the design and delivery of science content courses for elementary teachers. Relevant issues included but were not limited to:

1. Science is just one of several major areas of study for elementary teachers. Elementary teachers must develop a broad background of knowledge across content areas as well as in the psychological, emotional, and social development of children. What role does a science content course play in relating science knowledge to children and the general elementary curriculum?

2. A large portion of the general public lack adequate background in mathematics and the sciences to understand important ideas in contemporary science. Many elementary teachers fall into this category. To what extent does a science content course solicit participation from those who have purposely avoided the subject?

3. Elementary teachers play a significant role in developing children's interests in science. They are in a position to foster appropriate cognitive and social skills necessary for engaging in investigative activities and learning hierarchically structured knowledge. How should science content courses teach cognitive skills for learning and investigating in science?

4. College and university faculties are often not rewarded for high-quality teaching in courses for non-majors. Consequently, even if there are appropriate courses for elementary teachers, they are often taught by new or temporary faculty or by graduate teaching assistants. Regular faculty do not work on developing the course over time nor do they learn how to motivate prospective teachers. What responsibility do departments of science have in elementary teacher education?

5. Science content for elementary teachers must cut across traditional science disciplines and therefore involve several science departments. With limited resources and a limited number of student-credit-hours to divide up, science departments find it difficult to staff and maintain course sections that promote interactive instruction and that include laboratory work. How should content courses be designed and managed to provide appropriate instruction across science disciplines? The Center production staff and the AETS content guides also faced challenges associated with delivering coursework via video tape. It was clear to all from the beginning that content course could not stand on video tape alone. The premises of hands-on, interactive learning presented in the programs could not be achieved by simply watching. With this in mind the guides and staff confronted several issues, which concerned how to design and distribute the video, print, and computer materials to:

1. integrate on-sight laboratory work at colleges and universities
2. promote on-sight discussion and student interactions
3. promote a total experience that models instruction consistent with research-based practices
4. promote understanding of concepts most importance for the elementary years
5. promote appropriate assessment practices

The content and presentation format may be of value to more than the target audiences of elementary teachers. Unique video demonstrations, expert interviews, video from classrooms and interviews with students, and the cross disciplinary nature of the series makes the programs potentially useful for: (a) prospective elementary teachers (the primary audience), (b) prospective middle school teachers, (c) inservice teachers, (d) school administrators, (e) 2-year and 4-year college science faculty, (f) 2-year and 4-year education faculty, and (g) parents.

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SCIENCE EDUCATION IN AN URBAN ELEMENTARY SCHOOL: CASE STUDIES OF TEACHER BELIEFS, CLASSROOM PRACTICES, AND STAFF DEVELOPMENT

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Science Education in an Urban Elementary School: Case Studies of Teacher Beliefs, Classroom Practices, and Staff Development

Through a case study approach, the state of science education and attendant staff development practices in an urban elementary school were examined in detail. Observations made from the perspective of a science education specialist, an educational psychologist, and an expert elementary teacher were triangulated to provide a data-rich set of perspectives from which elementary science instruction could be examined. Findings revealed that teachers were more poorly prepared than had been anticipated, both in terms of science content knowledge and instructional skills, but also with respect to the quality of classroom pedagogical and management skills. Particularly significant from a science education perspective was the inconsistency between how they perceived their teaching practice (a hands-on, inquiry-based approach) and the investigator-observed expository nature of the lessons. Lessons were typically expository in nature, with little higher-level interaction of significance. Based on these findings, a staff development program initiated by the teachers in this school was implemented to provide the means by which teachers could improve their practice. Implications for practice and the associated needs for further staff development among urban elementary teachers is discussed within the context of these findings.

Background

Researchers, policymakers, and stakeholders recognize the urban public schools suffer from a myriad of problems (Kozol, 1991; Council of Great City Schools, 1994). Abundant statistics describe American urban public school systems as lacking adequate resources to serve the substantial number of economically disadvantaged and highly mobile students enrolled in these schools (Committee for Research on the Education of Students Placed at Risk, 1996). The state of science education in urban public elementary schools is particularly unfavorable. Large differences exist among the science achievement shown by students in urban schools in comparison to students from more privileged backgrounds (Clewell, Hannaway, de Cohen, Merryman, Mitchell, & O'Brien, 1995).[1] Furthermore, urban minority students rarely take high school electives that prepare them for science related careers or college majors, a situation sometimes attributed to their limited elementary school science education (Garcia, 1988). Female students, in particular, tend to be excluded (Beane, 1988).

Surprisingly, despite these findings regarding the outcomes of science education in urban schools, little objective empirical data describes what science education actually looks like in urban public schools. The purpose of the current study is to describe what actually happens during typical science lessons in an urban elementary school with a high percentage of low-income minority children and to examine teacher's beliefs about their classrooms and their students. Teachers' perceptions of their work and their expectations of students, which can be revealed through interviews, as well as their daily instructional practices, which can be revealed

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[1] Although urban students scoring at the lowest level on standardized achievement tests made small performance gains during the decade prior to 1995, the performance gap between them and other students remains large. Although urban students scoring at the lowest level on standardized achievement tests made small performance gains during the decade prior to 1995, the performance gap between them and other students remains large.

through observation, are key factors that teachers bring to the classroom (Beane, 1988). Because teachers' beliefs and practices impact student attitudes and academic success in science (Beane, 1988), we examined both in the present study.

Context of Study and Methodology

The current study was conducted at an urban elementary school (K-8) in a large Midwestern industrial city. According to district records, the school specializes in mathematics and science. Ninety percent of the teachers are female and 87 % of the teachers are ethnic minorities (Black and Hispanic). Approximately six hundred children attended the school; 87 % of the students are from families whose incomes fall below the poverty level and more than 99 % of the students are Black. The school is located in an area hard hit by unemployment following the closing of nearby steel mills a decade ago. Signs of economic and social distress appeared as unemployment grew within the area. For example, city records document increased dependence on public assistance, substance abuse, and gang problems in the neighborhood served by the school.

In accordance with contemporary recommendations for conducting case studies in schools, the data collection procedures were triangulated (Maxwell, 1996). Data were collected from interviewing and observing the same teachers, so as not to bias conclusions by focusing on only one data source. Each researcher independently analyzed the same observations. Producing three perspectives on the same classroom event allowed the researchers to build a more detailed picture of the teaching and to validate their conclusions across the interpretation of three observers.

Teacher interview.

Each teacher participated in a semi-structured interview designed to elicit teachers' perceptions of their students and their classrooms. Each interview lasted approximately forty-five minutes. Teachers described the science curriculum, typical classroom activities, and their role as a science teacher, including what they liked most about their current teaching practices and what they would like to change. Teachers were asked to comment on the impact of mandated achievement tests on their science teaching. A series of questions addressed teacher's ideas about their current students' knowledge, learning, and individual differences. Teachers also explained what both "inquiry in science" and "hands-on/minds-on" meant to them. In addition, teachers provided information about their educational background and experience. Interviews were transcribed verbatim to produce "rich" data (Becker, 1970).

Classroom observations

The authors of this study videotaped a science lesson in each participating teachers' classroom. A previous two-year relationship existed between the teachers in the study and the educational psychologist. This increased familiarity led to a high level of comfort between the teachers and the researchers. This familiarity further reduced the potentially disruptive effects of the videotaping. Teachers were told that we were interested in observing a typical lesson. These lessons were then analyzed independently by three researchers with different perspectives – a science education specialist, an educational psychologist, and an experienced elementary school teacher who had taught both second and seventh grades in a private suburban school.

Science Educator's observation scheme

The science education specialist described the lesson and collected data with respect to teacher- and student-initiated questions and answers. The question-and-answer data evaluates the extent to which the teacher promotes scientific literacy among all children including girls. First, cases were counted when the teacher directed a question to either the whole class, to an individual male student, or to an individual female student. Student's responses refer to either choral responses to the teacher's questions, or to individual answers or questions from female and male students.

Educational psychologist's observation scheme

The Educational Psychologist devised a coding scheme that was modified from prior observational studies of adult teaching of elementary school students within the framework of NCTM mathematics reforms (Lehrer & Shumow, 1997; Shumow, 1998). This scheme focuses on a number of the instructional strategies suggested by the science reform documents and entails coding each statement that the teacher made during the lesson on two dimensions. The first dimension, "involving", characterized (yes/no) whether the teachers statement prompted the students to engage in thinking (higher order thinking). The second dimension, called "purpose," categorized the function the teacher's statement served in the lesson. These purposes include focusing on either a) knowledge, givens, or problem definitions, b) moving the flow of the lesson forward, c) elaborating including hypothesizing, comparing and contrasting, explaining, or justifying, d) modeling including demonstrating, creating representations, or analogizing, e) managing student behavior, and f) attending to interruptions.

Expert teacher's observation scheme.

The expert teacher viewed the videotapes and took notes. A narrative description was composed, outlining the teaching strategies and student responses to the lesson from the perspective of an expert practitioner. This perspective, based on successful teaching experience and practice informed by continued graduate education, provided a *gestalt* view of the classroom interactions, to complement the narrower foci of the science educator and the educational psychologist.

Results and Discussion: Part I

The data gathered by the science educator was collected and summarized in Table 1. Results from the educational psychologist's data collection scheme is presented Tables 2.

Table 1 reveals a variety of issues related to the use of questions and questioning to develop interactions among the teachers and students. In terms of male-female equity issues, results are mixed. Teacher One successfully contacted all boys during the lesson, yet addressed only seventy percent of the girls. Teacher Two interacted with some ninety one percent of the girls and eighty three percent of the boys. Teacher Three, like Teacher One, interacted with more boys than girls: seventy six percent and sixty four percent, respectively. Teacher Four interacted with only thirty eight percent of the boys and fifty five percent of the girls in the classroom. While there was no consistent pattern evident of discrimination directed toward either boys or girls, the level of interaction would ideally be higher to promote the scientific literacy goal of "Science for all Americans."

The instructional functions captured in Table 2 are particularly notable in terms of the low number of interactions related to the modeling of scientific concepts. The most successful teacher in this regard was Teacher One, who devoted some eleven percent of her utterances toward the goal of promoting modeling. Strikingly, the two seventh grade teachers (Teacher Three and Teacher Four) were recorded as having done none of this during the duration of their science lessons. Indeed, the two seventh grade teachers devoted the plurality of their lessons toward more procedural issues, e.g., "open your books," "turn the page," etc.

Table 1

Teacher-Student Question and Answer Interactions During the Lesson

	Teacher One			Teacher Two			Teacher Three			Teacher Four		
	Class	Male	Female	Class	Male	Female	Class	Male	Female	Class	Male	Female
Number of Questions from Teacher	50 (49.5%)	27 (26.7%)	24 (23.8%)	27 (25.2%)	50 (46.7%)	30 (28.0%)	27 (40.9%)	20 (30.3%)	19 (28.8%)	3 (21.4%)	7 (50.0%)	4 (28.6%)
Responses from Students to Teacher	45 (46.4%)	25 (25.8%)	27 (27.8%)	11 (13.3%)	48 (57.8%)	24 (28.9%)	8 (15.4%)	27 (51.9%)	17 (32.7%)	0 (0.0%)	9 (69.2%)	4 (30.8%)
Number of Students Addressed, by gender	--	9 (69.2%)	10 (100%)	--	11 (91.7%)	10 (83.3%)	--	10 (76.9%)	11 (64.7%)	--	5 (38.5%)	5 (55.6%)

Teacher 1 Class $n = 23$ ($n_{boys} = 13$, $n_{girls} = 10$)

Teacher 2 Class $n = 24$ ($n_{boys} = 12$, $n_{girls} = 12$)

Teacher 3 Class $n = 30$ ($n_{boys} = 13$, $n_{girls} = 17$)

Teacher 4 Class $n = 22$ ($n_{boys} = 13$, $n_{girls} = 9$)

Table 2

The instructional functions served by each teacher's classroom discourse

	Teacher 1	Teacher 2	Teacher 3	Teacher 4
Information Focus	26.8 %	26.4 %	31.6 %	13 %
Sequential Flow	36.4 %	30.9 %	56.8 %	69.6 %
Elaboration	11.7 %	4.5 %	5.8 %	0
Modeling	11.4 %	7.3 %	0	0
Dealing with Interruption	4.1 %	7.3 %	1.9 %	8.7 %
Classroom Management	9.6 %	23.6 %	3.9 %	8.7 %
N of coded utterances*	437	220	155	69
Interactions per minute	4.9	2.9	2.8	1.3

*Note. Teacher 1's lesson was approximately 1-_ hours. Teacher 2's lesson was 75 minutes. Teacher 3 and 4's lessons were approximately 55 minutes.

Each teacher shared the ideas and experiences that informed their views of teaching and learning in science during an interview. Teachers also described their teaching approach and their students. The interview results were followed by a description of classroom observations conducted by the science educator, the educational psychologist, and the expert teacher. The implications of the findings were summarized as follows.

The cases examined in this study revealed a number of issues of critical importance to the implementation of effective science teaching. First and foremost, there was a disconnect between what the teachers said they did (or were trying to do) versus what observer's saw them doing in the classroom. Words such as "facilitator" and "hands-on science" are well-represented in their descriptions of their practices and their teaching beliefs. However, none of the classroom observations indicated that anything remotely approaching inquiry based science instruction is taking place.

This disconnect brings with it certain implications for evaluation of science programs. Given the great disparity between what teachers stated was their practice and the reality of the situation, the value of self-reported program documentation and evaluation must be called into question. All of the teachers believed that they practiced an inquiry-based approach to teaching science, but this view was not evident in any of the cases observed. The "activity mania"--evident in Teacher Four's classroom practices and the description of her practice--equates the manipulation of materials with an inquiry-based approach.

Interestingly, the evaluations of the staff development programs they participate in tend to be teacher self-report. Judging from their use of terms like "hands-on", "critical thinking", and "scientific process" the teachers picked up on the "talk" about current recommendations for science teaching and shared it in turn with the authors of this study.

The reliance on the textbook should not have been surprising given the teachers' limited educational backgrounds. The observations revealed glaring limitations in the teachers' professional and content area knowledge. This may be because the teachers were not adequately prepared academically. The strikingly low average score for ACT tests reported at the institutions that each of the teachers attended suggests that these colleges served a student population with low levels of academic achievement. In terms of science background, the teachers took little science content in college. The recent graduate could not even remember what area of science her coursework was in, even though was seeking state certification to teach science. The academic qualifications and certification of teachers is subject to public policy. These cases suggest that current policy is not adequately fostering programs that prepare urban teachers to teach science.

Content knowledge in science is, of course, necessary in order to teach the subject. It is not sufficient, however. Teachers also need pedagogical skills. The inadequate professional skills these teachers brought to their classrooms were revealed in the poor understanding that they had of what their students knew and in what they believed the students were capable of learning. Not one of the teachers could describe their students' scientific knowledge or understanding. This is alarming in view of the pedagogical importance of being able to identify student's knowledge.

There are several implications of this problem. For one, teachers need to learn how to assess their students' knowledge and how to utilize that assessment in planning instruction. For another, the teachers have little institutional support for making assessment a formative factor in their instruction. Although the state achievement tests were acknowledged as a factor driving the curriculum, these test results are not returned to the schools until after the end of the school year. As a result, teachers do not even get a general sense of how the individual students perform while they are still teaching the students. It seems that the extensive resources and efforts directed towards these mandated tests might be redirected to more productive purposes, namely designing assessments that can be used by classroom teachers to inform their instruction throughout the school year.

Clearly, the need for more effective staff development programs has been underscored by the fact that these teachers have taken part in programs aimed at the promotion of inquiry-based science instruction. The key here is *effective programs*, since the content addressed in their staff development training (usually described as helping them to make science more "hands-on") did not appear to have had much observable impact on their actual practice. Certainly it did not help them change their practices from an expository to an inquiry-based approach to teaching science. Perhaps the short-term nature of the staff development programs was a factor. It is not likely that an occasional afternoon workshop will have a long-term impact on classroom practice. To this end, the educational psychologist and the science educator assisted in the implementation of several staff development initiatives in this school.

Part II: Implementing a Staff Development Program

In an effort to work in concert with the needs identified by the teachers in this study, staff development assistance was developed and offered to assist them in the implementation of an inquiry based science program. The need for continual staff development among teachers is implied by the proliferation of standards documents (AAAS, 1993; NRC, 1996) addressing science education. In particular, the National Research Council's (1996) National Science Education Standards moves beyond the implicit to state that teachers should "participate fully in planning and implementing professional growth and development" (p. 52). The policy of improving teacher skills in science education is a task that has been embraced by universities, states, non-profit organizations, school districts, individual schools and individual teachers (Joyce & Showers, 1988).

Staff Development in Science Education

The overall purpose of staff development is to develop a system in which teachers have the opportunity to regularly update and develop their teaching skills and knowledge (Joyce & Showers, 1988). The staff development needs in science education have had as one of their key components of developing the teacher's science content knowledge--and the teacher's prior knowledge--as part of the staff development process (Loucks-Horsley, Kaptian, Carlson, Kuerbis, Clark, Mele, Sachse, & Walton, 1990). To this end, staff development programs in science frequently expend significant effort developing the content knowledge of teachers in the various disciplines of science (New York City Board of Education, 1984; Carroll County Public Schools, 1985; Thompson & King, 1999).

Staff Development in Urban Schools

With the desire for inquiry-based science in conflict with the observation that over 90% of urban teachers typically teach though "direct instruction, lecture, rote and drill and practice" (ASCD Urban Middle Grades Network, in Hodges, 1996, p. 225; Silvertsen, 1993), the need for effective staff development is apparent. In addition to the pedagogical problems, content area preparation is likewise poor: only one-quarter of fourth grade public school students had teachers who reported that they were certified in the area of science (NAEP, 1998).

Elements from a retraining approach advocated by Bonja, Coogan, Lipman, & Rodgers (1986), primarily the need for careful and comprehensive planning to meet the needs of the teachers, were recognized and implemented. Further, given the challenges of teaching in urban schools, the high dropout rates, and the complex and critical needs of teachers in these schools, the need for effective staff development is particularly important (Hodges, 1996). Undertaking staff development in urban schools offers multiple challenges. Several issues are critical to success in the urban educational setting. Among these concerns are that all stakeholders understand and work toward a common goal (Stein, Norman, & Clay-Chambers, 1997). The lack of a shared vision disables the change process. In an effort to institutionalize a new culture of staff development, the staff development programs were developed around groups of teachers with similar interests. Research indicates the value of these professional communities within urban schools (Bryk, Camburn, & Louis, 1997).

Developing the Programs

The four teachers described previously were involved in the development of three different instructional programs. The units were to be interdisciplinary in nature, with content from mathematics, science, and technology forming the core of the instruction. Staff development assistance and guidance were offered to develop each of the programs. An educational psychologist and a science education specialist, both with previous elementary and middle school teaching experience, contributed their expertise. Teacher One was involved with the creation of a weather unit, Teacher Two was involved with the creation of an aviation unit, and Teachers Three and Four contributed to the creation of a science unit using solar cars as a vehicle for better understanding motion. For the purposes of this brief study, the report of the implementation of the solar car investigation will be presented here. The detailed results from the development and implementation of the other projects are currently being composed.

Developing the Solar Car Unit.

The idea for the development of an instructional unit using toy cars powered by solar cells came from a group of teachers in the building. The teachers were responsible for instructing math, science, and technology coursework. The intention for the teachers was to have students construct and analyze the motion of the solar cars. This would allow the students to construct an understanding of how the motion of the solar cars was altered by changing gear ratios, increasing the wheel size, adjusting the surface of the wheel (thereby affecting frictional forces) and the like. To measure gains in student knowledge, a science education expert--who served as the workshop facilitator--developed a pre- and post-test instrument to be administered to the students.

Teachers were introduced to the activity during an afternoon workshop. Cooperative groups of teachers constructed sample solar cars and developed their own understanding of what a successful car required. A number of adjustments in terms of gear ratios, wheel sizes, and the distance from the light source to the solar panel were made by the teachers. Connecting their understanding of how these adjustments to the change in speed that resulted occupied the teachers for most of the time allotted for the workshop.

Developing a broader conceptual understanding was undertaken as the workshop facilitator led the teachers through the development of a concept map as a means of organizing the teacher's findings. The map attempted to organize how the changes in the cars' motion were related to some underlying physical principles. The concept map is presented in Figure 1.

The decision was made that each of the ideas identified though the concept map would provide a topic for which a lesson plan would be constructed. Together, the lesson plans would be linked to provide the overall structure for an instructional unit. To provide further support for the construction of the cars and the development of the lesson plans, participants were given copies of a pamphlet created at Argonne National Laboratory on the topic of studying motion through the use of solar cars. Detailed descriptions of activities provided in the pamphlet--which fortuitously matched the concepts developed independently on the concept map--were to be developed into complete guided discovery lessons (in a format consistent with one suggested by Howe & Jones, 1993) by the teachers. The workshop facilitator created a sample lesson plan to provide a model.

Figure 1. Teacher-constructed concept map

This figure is located at
http://www.cedu.niu.edu/scied/images/concept_map.gif

Participants in the workshop were challenged to derive connections between and among their disciplines that could be addressed though the use of the solar cars. They all also agreed to bring their completed solar cars to class during the following week to challenge students to create ways in which the cars could be made to go faster, straighter, slower, to pull a greater mass, and so on. The equipment needed to carry out the activities in each classroom were identified, and management issues related to the implementation of the solar car activity were addressed.

Obstacles Encountered During Unit Development. The first meeting took place in mid-January 1998. A follow-up meeting was scheduled for one week later to gauge progress. This group of teachers was composed of a larger group of teachers drawn from both the local school and surrounding area. Teacher Three and Teacher Four were both part of this curriculum development group. Progress was stymied for several reasons, including the absence of one lesson. The guided discovery lesson was developed and implemented as part of the staff development programs the teachers were involved in. Teachers One and Two created lessons to promote inquiry-based teaching; Teacher Three and Teacher Four did likewise. Teachers Three and Four were involved in the development of the solar car activity; Teacher One worked on the development of instruction around the topic of the seasons, and Teacher Two participated in the development of a unit on flight. The direct instruction lessons were captured before the implementation of the staff development programming.

Classroom Observations. The classroom interactions between teachers and students are presented here, based on the coding scheme described previously. The methodology employed for data collection was the same as used by the educational psychologist and described above. Teacher's interactions with students were coded according to the instructional purpose intended.

Table 3

The instructional functions served by each teacher's classroom discourse (Grade 2 and Grade 4 teachers*)

	Teacher One: Direct Instruction Lesson	Teacher One: Guided Discovery Lesson	Teacher Two: Direct Instruction Lesson	Teacher Two: Guided Discovery Lesson
Information Focus	26.8%	19.1%	26.4%	4.3%
Sequential Flow	36.4%	39.1%	30.9%	42.6%
Elaboration	11.7%	17.6%	4.5%	--
Modeling	11.4%	8.6%	7.3%	3.5%
Dealing with Interruption	4.1%	2.6%	7.3%	3.5%
Classroom Management	9.6%	13.1%	23.6%	46.1%
N of coded utterances	437	466	220	141
Interactions per minute	4.9	5.2	2.9	1.9

*Note. Teacher 1's lesson was approximately 90 minutes long. Teacher 2's lesson was 75 minutes in length

Post test. Students in Teacher Three's class were scored on responses to a pretest and posttest measure of concepts related to force and motion and to the use of the scientific method. There were no significant differences between scores on the pretests and posttests.

Teacher One. Teacher One's results show fairly consistent behaviors between the direct instruction and guided discovery lessons. The greatest change was the percentage of statements related to focusing students on the information, showing a dropping from 26.8% of recorded

Table 4

The instructional functions served by each teacher's classroom discourse (Grade 7 teachers*)

	Teacher Three: Direct Instruction Lesson	Teacher Three: Guided Discovery Lesson	Teacher Four: Direct Instruction Lesson	Teacher Four: Guided Discovery Lesson
Information Focus	31.6%	17.9%	13%	--
Sequential Flow	56.8%	43.9%	69.6%	80%
Elaboration	5.8%	2.4%	--	--
Modeling	--	--	--	--
Dealing with Interruption	1.9%	2.4%	8.7%	--
Classroom Management	3.9%	33.3%	8.7%	20.%
N of coded utterances	155	123	69	10
Interactions per minute	2.8	2.2	1.3	0.2

*Note. Teacher 3 and Teacher 4's lessons were approximately 55 minutes in length.

utterances to 19.1%. Modest increases were observed in sequential flow (36.4% to 39.1%) and classroom management (9.6% to 13.1%).

Teacher Two. From the data, Teacher Two's interactions with students changed drastically from the direct instruction lesson to the inquiry-based lesson. The focus on the information dropped from 26.4% of recorded utterances to only 4.3%. Sequential flow interactions increased from 30.9% to 42.6% of all recorded statements. Classroom management interactions nearly doubled from 23.6% of utterances to 46.1%.

Teacher Three. As can be seen from the data, the most significant change for Teacher Three's interactions were in the area of classroom management. The number of utterances related to classroom management issues increased by a factor of 8.5, with the percentage increasing from 3.9% to 33.3% of all recorded utterances. Information flow and sequential flow interactions both decreased, from 31.6% to 17.9% and 56.8% to 43.9%, respectively.

Teacher Four. Teacher four's results are striking in terms of the types of interactions eliminated from her classroom discourse during the implementation of the inquiry-based lesson. Information focus and statements dealing with classroom interactions both disappeared. Sequential flow statements increased to 80.0% from 69.6% and classroom management statements more than doubled, from 8.7% of interactions to 20.%.

Overall Results, Discussion, and Implications

The findings from the classroom observations bring to light several issues regarding teaching and teacher preparation. The key point to be extracted from this is that for a staff development program to be effective, a broader look at the skills and knowledge base of a teacher needs to be considered. The staff development programs for the teachers at this school concentrated almost exclusively on the science content knowledge required to present inquiry based lessons effectively. It was assumed, erroneously in most cases, that the teaching skills would transfer as well. Given the enormous increase in classroom management utterances among all but one of the teachers, more time should have been devoted to improvements in pedagogy.

As addressed previously, each teacher shared the ideas and experiences that informed their views of teaching and learning in science during an interview. Teachers also described their teaching approach and their students. The implications of the findings were summarized as follows.

Individual teacher skill levels--both pedagogical and content-related--provided significant challenges to the process. The experiences in this project--the Solar Car Unit, in particular--were reminiscent of the findings reported by Huntley (1999). Results from Huntley's study suggested that for interdisciplinary teaching to find success requires that a number of factors be in place before a reasonable measure of success may be encountered. Among them are that:

> 1. The teachers need more formal coursework in the individual disciplines for efforts at integration to be successful…[and]
> 2. Teachers must be able to function within the existing structures and constraints of their individual schools; and finally,
> 3. Teachers who embrace interdisciplinary teaching find more success when they are in a working relationship with peers who share similar views. (p. 66)

Regarding the first of Huntley's points, most of the teachers involved in the projects had very little formal training in science. This was evident in part due to the rapid attrition from the group participating in the solar car unit project. Rather than build on the collective knowledge of the group as subject area specialists, they deemed their own lack of knowledge of the other disciplines to be sufficient cause to drop out of the project.

Point 2 is clearly an area in which the development and implementation of the solar car project faltered. The challenges in the school--frequent and unplanned changes within the daily schedule, to cite one example--caused more than one meeting between teachers and the science educator to be cancelled. Promised for assistance in the form of release time—to plan the structure of the solar car unit was missing as well. Related to this, the *perceived* sense that teachers did not have access to tools such as telephones proved destructive to the goals of the staff development project as well.

The final point finds further support is a necessity in the context of the solar car activity. Momentum was lost early in the implementation of the project when the majority of the teachers declined to return for further staff development and program planning sessions. This left Teacher Three virtually alone in the development of the project. And as a first year teacher, she was hardly prepared to deal with either the demands of planning integrated curriculum or of navigating the waters of the school culture.

A point not identified by Huntley (1999) but evident in this study was the role of the fundamental teaching skills possessed by the teachers. Based on the observation scheme developed by Shumow (1998), teacher management and inquiry skills were often quite poor. Instructional and management skills are so poor as to render a guided discovery, inquiry-based lesson far less productive than the traditional direct instruction lesson. The impact of their management skills is shown dramatically in Table 4. Direct instruction lessons taught by these teachers showed far greater involvement of students with higher levels of thinking and engagement than did the guided discovery structured lessons. In several cases, incidence of corrective feedback was higher by enormous amounts during the hand-on activities--as much as a factor nearly nine in one instance. Clearly, the quality of instruction is notably low when the largest plurality of student-teacher interactions are related to admonishments and controlling pupil behavior.

What teachers claimed they needed--*help, materials and expertise* (see King, Shumow & Lietz, in press) --even when provided, appeared to make no difference in their teaching. Open-ended interviews with the teachers during the development of the inquiry-based curriculum had each of the participants stating that among their critical needs were additional adult help, science materials, and development of their expertise in the content area they were teaching. Regarding additional adult help, Teacher Two stated the following:

> The lack of self-discipline within the children [is a primary concern]. There needs to be more self-discipline and it would be nice if we had an aide. I know I'm dreaming but that would be nice. Indeed, it would be nice to have an assistant on the hands-on day especially because the children are not able to handle all the departmental walking and it would be nice to have a program that the teacher brought them to class and stayed with them so there would be two teachers in the classroom at one time. That would help a lot.

Regarding the need for content area assistance, Teacher Three mentioned the following:

> I feel the least comfortable with the lab activities. I know I need help in that area, exactly how to go about doing more lab activities and have them working in larger groups and things of that nature I've found to be somewhat difficult for me.

Given the need for students to be successful, the assessment of student knowledge revealed that they had substantial, though superficial, knowledge of force, motion, and the scientific method. This level of understanding remained intact, and without change, after the students experienced the solar car activities. Simply allowing students to run free with an activity—as is what essentially happened in the solar car activities--demonstrated the real need that a guided discovery lesson be *guided.* As addressed in the follow-up interviews, though the teachers described themselves as advocates of hands-on learning and as facilitators of learning, their practices fell far short of their vocabulary. The poor pedagogical skills combined with marginal content knowledge placed students in a situation in which essentially no learning took place.

In terms of findings for staff development, the program facilitators demonstrated reasonable care to ensure that the needs of students and faculty alike were met during the development of the instructional units. Factors above and beyond the individual teacher's control continuously compounded challenged the implementation of the program. Erratically and unpredictably scheduled school days were only one of many barriers to effective staff development.

The sense of "learned helplessness" among the teachers was palpable. Though they had ample opportunity to improve the circumstances related to their teaching, they perceived themselves as helpless, virtually victims of what they perceived as a system indifferent to their situation as classroom teachers.

Teacher investment in the process, guaranteed by the principal, was not in evidence to the degree it that had been expected. Despite a strong working relationship between the teaching staff and the university personnel, other teachers in the school spread rumors. These rumors suggested that the purpose of the partnership was rather more insidious, with the science educator and the educational psychologist as tools of the principal to seek out and eliminate poor teachers. Teacher Three specifically mentioned during a conversation in a hallway that it was common knowledge among the teachers that the university personnel were present only as "spies" for the principal.

The ultimate tragedy is what happens to the students in a struggling system such as this. The findings from the pretest and posttest suggest that they have a reasonable, albeit superficial, understanding of the principles underlying the scientific method and of the content area examined. The time spent in one case playing with solar cars--with the construction of cars as the ultimate goal--was lost instructional time, and could have been reasonably expected to have moved the students from their accurate but limited understanding to something more detailed.

Producing more effective teachers is a task of not only the schools and colleges of education, but of the local schools and school districts. Content knowledge, pedagogical knowledge, and a school climate that treats students and teachers with compassion and respect are all ingredients that must be included. It is hoped that the findings of this study will help to direct future research in this critical area.

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SHIFTING TOWARD INQUIRY SCIENCE TEACHING: THE STORY OF SECONDARY SCIENCE TEACHERS WORKING ON EMERGENCY PERMITS

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We live in a period of dramatic changes in the science education community. Research results published in various ways (monographs, journal articles, books, conference presentations), as well as the *National Science Education Standards* (National Research Council, 1996) recommend that science should be taught in the same way it is built -- using inquiry. In scientific inquiries students are the ones who ask the question, devise ways to answer, collect and analyze data in the process of knowledge development, plan and present their findings and take into consideration constructive criticism (National Research Council, 1996).

Despite the numerous state and national findings and recommendations, practitioners at all levels of the science education community are involved in science teaching and learning in ways that are inconsistent with inquiry science. This study analyzes the practice of science teaching and learning at the secondary school level as implemented by 16 secondary pre-service teachers working on emergency permits. It also looks at the necessary elements in order to facilitate the recommended change toward inquiry science teaching and learning.

Emergency Permits

Emergency permits are allocated to practicing pre-service teachers who are in the process of completing their credentials. This category (emergency permits) emerged as the need for teachers in certain areas of the US (mainly urban - such as New York, Los Angeles) exceeded the availability of qualified teachers. School districts changed their policies in order to accommodate the new situation by allowing individuals with a defined minimum qualification level (in terms of content) to enter the classroom and teach. Pre-service teachers working on emergency permits are given a certain number of years (5 years in the Los Angeles area) to complete their certification requirements (content and education courses). They also need to complete a minimum of six semester credits per year in order to ensure the annual renewal of their emergency permit. These individuals teach in their own classroom during the day, and enroll in afternoon and evening courses to complete their certification requirements. The term pre-service in their case is rather confusing as these individuals teach every day in their own classrooms. The term pre-service in the case of emergency permits is used to suggest that these individuals are still working toward their certification as a secondary teacher.

The Four-Stage Model

The study uses as background the Four-Stage Model for the shift toward inquiry science (Moscovici, 1998a; Moscovici, 1998b). The model suggests that science teachers go through the following four stages in various combinations during their teaching careers: 1. textbook science; 2. activitymania; 3. imposed inquiries; and 4. personal inquiries.

Teachers acting according to the first stage - using textbook science - use the textbook as the main (and often the only) science material in order to teach science. The science curriculum in these classes moves from reading the text, to answering questions at the end of the chapter or on worksheets, to multiple choice tests supplied by the textbook editor.

Classes that use activitymania, or the second stage in the Four-Stage-Model (Moscovici & Nelson, 1998) show students busy with disconnected and short hands-on activities that usually remain at the level of fun and do not promote scientific inquiries. Students are presented with the problem, "the" way to solve it including the Materials and Methods section, expected results, and a short explanation of the scientific phenomenon that they "observed." The activities are self contained and do not lend themselves to inquiries as they usually "work" and all the students record/observe the expected results and reach the same accepted conclusion.

In the third stage of the model - imposing personal inquiries - the teacher imposes the problem, the solution, the results, and the explanation on students. The difference between the third stage (imposing personal inquiries) and the second stage (activitymania) is that in the third stage, the teacher investigated (inquired) a problem and, much like the college science professors teaching within their narrow area of specialization, they impose their personal research on the students in class.

The fourth stage - having students involved in their personal inquiries - is the stage when students come up with a researchable question, devise ways to answer it, experiment and collect data, organize and interpret data, and develop scientific knowledge along the way (as recommended by NRC, 1996). As different students or groups of students come up with different questions, the science classroom resembles a research laboratory (Moscovici & Carty, 1999).

Design and Procedures

This study which involved 16 secondary science teachers enrolled in a secondary science methods course at our university, is interpretive (Gallagher, 1991; Erickson, 1986; Eisner & Peshkin, 1990). Data for this study was developed from surveys (completed by 14 out of the 16 participants) followed with qualitative semi-structured interviews. Multiple member checks with participants and with individuals who were not directly involved in the study (Guba & Lincoln, 1989) as well as the use of triangulation (the process of contrasting data developed using a variety of techniques - Berg, 1989) added to the validity of the results presented below.

Results

Out of the 16 secondary pre-service teachers working on emergency permits who finished the Secondary Science Methods Course, only 14 evaluated their experienced and preferred teaching techniques using the Four-Stage Model in a survey form (Moscovici, 1998a & 1998b). Survey results are summarized in Table 1. Students rated themselves (on both experienced and preferred teaching techniques) from using mainly a textbook approach to science teaching (#1, 2, 6, 7, 8, 10, 12, and 13) to working on facilitating the development of students' inquiries in their classrooms (#4 and 9). In between were pre-service teachers who practiced mainly activitymania (#3, 5, 9, 11, and 14) and pre-service teachers who imposed their personal inquiries (which included the scientific question, the way to inquire, and the expected results) in their classrooms (especially #4).

Table 1

Experienced versus preferred teaching techniques as reported by secondary science pre-service teachers working on emergency permits

	Experienced				Preferred			
Student	Textbook	Activitymania	Imposed Inquiry	Personal Inqury	Textbook	Activitymani	Imposed Inquiry	Personal Inquiry
1	60	20	10	10	40	20	10	30
2	65	35	0	0	30	10	30	30
3	30	30	20	20	10	10	20	60
4	10	10	75	5	5	10	40	45
5	30	45	15	10	20	40	20	20
6	50	10	25	15	20	40	30	10
7	50	40	10	0	25	25	25	25
8	40	20	20	20	10	30	25	35
9	20	50	5	25	30	0	0	70
10	50	5	40	5	30	15	30	25
11	20	30	20	20	5	10	5	75
12	80	20	0	0	20	20	30	30
13	50	5	40	5	25	15	40	20
14	20	50	20	10	10	30	30	30

The relatively small sample that completed the surveys (*n* = 14), as well as the variability in their science teaching practices required consideration of substantive significance as implied by the averages reported in Table 2. There is a pattern in Table 2 showing that overall the participants in this study were discontent with their experienced practices and wanted to shift their science teaching techniques from textbook science (41% in the experienced) toward the use of scientific inquiries (36% in the preferred).

Table 2

Averages of the experienced versus preferred teaching techniques as reported by secondary science pre-service teachers working on emergency permits (n = 14)

	Textbook	Activitymania	Imposed Inquiry	Personal Inquiry
Experienced	41%	27%	20%	11%
Preferred	20%	20%	24%	36%

Data reported in Table 2 was also reinforced by statements made by participants during various interviews. For example, student #12 is teaching in an environment where she has no support from the school to improve her practices. She became bored using textbook science, and went through activitymania after she discovered the large amount of ideas presented in various texts and collections of science activities, as well as the large amount of low-cost laboratory activities presented as laboratory triggers during class. During the Secondary Science Methods course science teachers were shown how they could use variability in lab results as the basis for science inquiries. Student #12 used that idea in her classes and encouraged her students to engage in scientific inquiries. At that time she began enjoying teaching science in her classes.

Student #4, on the other hand, enjoyed her science education, and applied principles of inquiry during her teaching career. Her school is very supportive and she receives all the help she needs (both in terms of curriculum and materials). The high percentage of Imposed Inquiry (third stage of the Four-Stage Model) in her experienced environment is due to the fact that many students "are trying to find the 'right' conclusion. I don't think they realize the amount of openness available in writing their conclusions." She would like to have her students understand and take advantage of the process of scientific inquiry with both the responsibility (finding resources, evaluation information, experimenting) and the freedom involved (analyzing and interpreting data).

This study also revealed the fact that the variability in teaching practices is not directly related to the fact that these pre-service teachers were employed on emergency permits. There seems to be a stronger correlation between the practice of science inquiry in classrooms and the science experiences of the participants (e.g., their experience with open ended laboratories, anomalous data) as well as their perceived levels of support existent in schools (e.g., curricular support, mentorship, available resources). At this point in time this statement is based on anecdotal data and more research needs to be done in order to establish reliable correlation and move teaching practices of pre-service teachers working on emergency permits toward scientific inquiries - practices that are consistent with the development of higher-order thinking skills.

Using the Four-Stage Model professional development from teaching textbook science to facilitating scientific inquiry, the study also explored the necessary elements needed in order to move from one stage to another. In order to understand each stage, teachers need experience as students and as teachers with each one of the stages. Modeling (observing another teacher teach using one of the stages of teaching science mentioned above) and reflecting (Schoen, 1987, Schulman, 1986, Nichols, Tippins, & Wieseman, 1997) are also necessary factors for the shift in teachers' practices. Shift also depends on the teacher's effort to enhance their practices or their discontent with their present (experienced) practices. Elements such as content enhancement, hands-on experimentation, peer and expert consultations, were found to be instrumental for teacher development in each one of the four stages (Moscovici, 1998a).

Contribution

Since the development of the Four-Stage Model of teaching science, I have used it numerous times with practicing teachers. Teachers at various levels in their careers identified themselves as belonging to the different stages of the model, and all of them wanted to develop the capability to involve their students in scientific inquiries. The model, as well as the elements necessary in order to move from one stage to another proved to be a helpful tool for teacher enhancement. Most pre-service teachers left the Secondary Science Methods class with a clear idea of where they were and what they needed to do in order to help their students get involved in scientific inquiries and develop higher order thinking skills.

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TECHNOLOGY ADVANCING A CONTINUOUS COMMUNITY OF LEARNERS (TACCOL)

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One of the implications of the Third International Mathematics and Science Study (TIMSS, 1997, 1998) is that methods of teaching in the United States need to be changed. The National Research Council's National Science Education Standards provide suggestions for reforms in science instructional practices. The National Council of Teachers of Mathematics have contributed three national documents for suggested changes in mathematics instruction [The Curriculum and Evaluation Standards for School Mathematics (1989), The Professional Standards for Teaching Mathematics (1991), and The Assessment Standards for School Mathematics (1995)].

Unfortunately, some teachers are unable to implement the suggestions for reform instruction due to insufficient support from their school districts and colleagues in their attempt to make changes in their instructional techniques (Carbone, 1998). One solution to this problem is well-designed professional development programs that provide teachers with the knowledge and support needed for implementing innovations in teaching and learning mathematics and science (Carbone, 1998; Harry, 1996).

Link-to-Learn Higher Education Initiative

In February of 1999, twenty colleges and universities in Pennsylvania were awarded funding from the Link-to-Learn Higher Education Initiative, "Integrating Technology into Teacher Preparation" (ITTP). The grants emphasized teaching with technology rather than teaching about technology. The projects funded were organized to ensure current and future teachers the ability to use technology to teach rigorous academic subjects in meaningful ways.

The ITTP funding complements Pennsylvania's recently adopted academic standards. The standards outline what students should know and be able to do at the conclusion of grades 3, 5, 8, and 11.

With the encouragement and support of Dr. Gail Grejda, Dean of the College of Education and Humans Services, Dr. Elaine Carbone, Mathematics Department, and Dr. Vickie Harry, Education Department, wrote a proposal on behalf of Clarion University. The Clarion project, Technology Advancing A Continuous Community of Learners (TACCOL), was funded in the amount of $330,500 matched by $125,000 from Clarion University.

Technology Advancing a Continuous Community of Learners (TACCOL)

TACCOL develops and implements an innovative environment for interfacing technology with mathematics and science education while achieving and maintaining systemic change in teacher education and K - 12 learning. The goal of the project is to provide professional development for higher education faculty, prospective teachers, and practicing teachers (cooperating teachers from area school districts) to enhance instruction in mathematics and science through the use of computers, graphing calculators, calculator based rangers (CBRs), calculator based laboratories (CBLs), and multiple probes .

TACCOL funds have purchased 64 laptop computers, 31 zip drives, 18 super drives, three Proxima projectors, 200 graphing calculators (TI-73s, TI-89s, and TI-83+s), eight viewscreens for the calculators, 28 CBRs, 16 CBLs, four sets of 16 different probes, client licenses for Office 98 and AppleWorks 5.0, hubs (for Internet access), ethernet cords, TI - GRAPH LINKs, Graphical Analysis software, and four portable storage carts. Each storage cart locks for security purposes and includes a power strip into which the laptops are plugged when not in use. The entire cart is then plugged into an outlet. This system allows the computers' batteries to recharge when not in use. Each computer battery holds its charge for about three hours (more than enough time for classroom use). In addition, each cart is stocked with viewscreens, CBLs, CBRs, zip and super drives, ethernet cords, and hubs. The portable carts can be transported into any classroom and facilitate the implementation of technology-based instruction including Internet access for all laptops.

Technology Competencies

As a result of this initiative, by the fall semester in the year 2000, participating university faculty, practicing teachers, and prospective teachers will possess the following minimum technology competencies:

- use word processing, spreadsheet, and database software and the appropriate hardware as tools for enhancing personal productivity and for teaching mathematics and science content.
- develop instruction using word processing, spreadsheet, and database software to increase student productivity and student content knowledge in mathematics and science.
- explore the Internet using www browsers to enhance instruction.
- create interactive instructional modules using PowerPoint.
- use telecommunications systems to receive and send e-mail messages, create listservs, and utilize the Internet as an instructional resource.
- integrate Calculator Based Rangers (CBRs), Calculator Based Laboratories (CBLs), probes, TI-89 calculators, and TI-73 calculators into mathematics and science instruction.

The competencies were developed collaboratively with the Education Department in the College of Education and Human Services, the Mathematics and Physics Departments in the College of Arts and Sciences, and basic education administration and faculty to improve content and pedagogical knowledge of university faculty, practicing teachers, and prospective teachers in the teaching and learning of science, mathematics, and technology.

Components for Implementation of Technology Instruction

To enable the university faculty, practicing teachers, and prospective teachers to acquire these competencies, Clarion University implemented the following professional development activities:

- incorporated a technology component (15 additional hours) to supplement the elementary and secondary mathematics and science methods courses during the fall 1999 semester.
- provided professional development opportunities for university faculty to learn the technology competencies. These opportunities enabled university instructors to integrate and model technology competencies in the teaching of mathematics and science in the content and methods courses for elementary and secondary education majors during the fall 1999 semester.
- provided professional development opportunities for practicing teachers who serve as cooperating teachers for Clarion University student teachers. These workshop were held during July 1999 and two follow-up sessions were held during the fall 1999 semester. These opportunities enabled teachers to integrate and model technology competencies in K - 12 classrooms which serve as sites for student teacher placements.

Through the infusion of technology in the mathematics and science curricula, a constructivist approach to teaching and learning was presented to university faculty, prospective, and practicing teachers through their attendance and participation in Link-to-Learn workshops at Clarion University. Through hands-on, activity based learning, educators in the Departments of

Education, Mathematics, Physics, Biology, and Chemistry modeled a technological approach to the teaching and learning of science and mathematics.

The technology competencies support the effective teaching of the Pennsylvania Academic Standards for Mathematics and the emerging Academic Standards for Science and Technology for grades K-12. Additionally, these competencies support science, technology, and mathematics constructivist teaching practices for primary, intermediate, middle school, and/or secondary teachers. To address these Pennsylvania Academic Standards, hands-on data gathering experiences were developed to be modeled by university faculty for preservice and inservice teachers. Further expansion of the basic usage of the technology in the mathematics and science classrooms will continue to enhance pedagogical practices as well as mathematical and scientific content knowledge.

During the funding period, this project directly serves approximately 55 prospective teachers, approximately 30 higher education faculty, and 110 cooperating teachers. Clarion University partnered with the following twelve school districts: Brockway Area, Brookville Area, Clarion Area, Clarion Limestone Area, Cranberry Area, Franklin Area, Keystone, North Clarion County, Oil City Area, Redbank Valley, Union, and Valley Grove to strengthen the relationship between the student teachers and the cooperating teachers in their attempts to infuse technology in the K - 12 classrooms.

A Continuous Community of Learners

The TACCOL project at Clarion will be sustained through continued university and school faculty professional development opportunities, curricular change, and the ongoing integration of technology into mathematics and science content classes. Since the university faculty who teach the mathematics and science content and methods courses have been trained to use the technology purchased by the grant, they are integrating the use of technology into general education and methods courses for prospective teachers as well as serving as models of exemplary instructional strategies. The prospective teachers are beginning to feel confident about integrating technology into mathematics and science classroom practices as a result of the technology component of their mathematics and science methods courses. The integration of technology was then infused into the curriculum of the methods courses that were offered during the spring semester for all mathematics and science secondary majors and for all elementary majors. The practicing teachers who participated in the summer workshops also are prepared to integrate technology into classroom practice as evidenced by the projects they conducted in their classrooms. Their presentations at the final follow-up session also exhibited evidence of student learning. During the spring 2000 semester, student teachers are matched with the cooperating teachers who participated in the summer workshops. They are presently working together to implement technology competencies into classroom practice. All future prospective teachers will use and learn to integrate technology competencies into their teaching after participating in the university's classes where the faculty continue to integrate technology in their instructional practices.

Additional institutional changes needed to sustain the project after the funding ends include curricular changes and ongoing support for retraining of new faculty. Course syllabi will need to be rewritten to include the technology competencies as requirements for teacher certification and then sent forward for approval by the Committee on Courses and Programs of Study (CCPS). The Advancing the Development of Educators in Pennsylvania through Technology Training (ADEPTT) Center at Clarion University will continue ongoing technology training for new faculty. Workshops will be offered for faculty to learn to use the technology purchased by the Link-to-Learn project on a regularly scheduled basis through the ADEPTT Center.

The university faculty, the practicing teachers and the prospective teachers comprise the continuous community of learners in the implementation of technology in their classrooms. The university faculty taught both the practicing and the prospective teachers; the practicing teachers are working in collaboration with the prospective teachers during their student teaching experience. The project directors collaborate with the cooperating teachers in supervising the student teachers. The growth of the continuous community of learners will strengthen the technologically-enhanced

instruction augmented by the Pennsylvania Academic Standards for Mathematics and the emerging Pennsylvania Academic Standards for Science and Technology.

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GLOBE CITIZEN SCIENTISTS WITH A SATELLITE CONNECTION

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Organization and Abstract

GLOBE ("Global Learning and Observation for the Betterment of the Environment") is a federally funded, environmental science and education program that puts into practice authentic learning, student-scientist partnerships and inquiry-based pedagogy. School children collect, share, and analyze data as a part of GLOBE. The 20 data collection protocols are in the areas of Atmosphere, Hydrology, Land Cover/Biology, Soil and Global Positioning Systems (GPS). In essence, then, the school children act as citizen scientists and their work in the remote sensing field gives them a satellite connection. GLOBE school sites now number more than 6,000 and can be found in all 50 states and more than 82 countries. Its inclusion in our urban schools, however, has been lagging. GLOBE is currently working on a modified set of protocols that would accommodate urban conditions and answer more urban-environment kinds of questions. At the same time, efforts are needed that would focus on helping our urban children become full participants in the GLOBE program.

This paper outlines one such effort. It is a (fully funded) 1999 Ohio Board of Regents Dwight D. Eisenhower Professional Development Program grant proposal with the name "Citizen Scientists with a Satellite Connection." Considerable interest was raised in this proposal at the AETS 2000 Conference and the author hopes that by disseminating the grant proposal through AETS channels and ERIC, others will be able to mold and modify it to fit their own needs. The headings of this paper correspond to the sections of the grant proposal.

Overview of the Project

"Citizen Scientists with a Satellite Connection" targets Ohio teachers of minority students for training in GLOBE (Global Learning and Observations to Benefit the Environment). GLOBE puts into practice authentic learning, student-scientist partnerships, and inquiry-based pedagogy. Teams of 5 middle-school teachers from 10 schools will attend a 48-hour summer workshop held at the Cuyahoga Valley Environmental Education Center and two 3-hour follow-up sessions for a total of 54 contact hours. A faculty person will visit their classroom on-site for the final contact hour. Also, 25 Cleveland State University preservice teachers will help the inservice teachers implement GLOBE in their classrooms as a part of the preservice teachers' field-service requirement for teacher licensure.

Schoolchildren collect, share, and analyze data as a part of GLOBE. Unlike traditional school science programs, in which students perform isolated experiments with no consequences for increasing scientific knowledge, GLOBE has students participate in actual science investigations led by scientists selected through a competitive grant process. In addition, students generate their own questions, working with fellow students both in the U.S. and 82 other countries to conduct investigations and share their findings via the Internet. Before their students can enter data on the GLOBE database, however, teachers must complete a training program in which they learn how to conduct the GLOBE protocols and gain experience with the learning activities in the GLOBE Teacher's Guide. The 20 data collection protocols are in the areas of Atmosphere, Hydrology, Land Cover/Biology, Soil and Global Positioning Systems (GPS). The learning activities put the data collection activities into an educationally meaningful context.

"Citizen Scientists with a Satellite Connection" fosters the successful implementation of GLOBE in classrooms of minority students in three ways. First, it trains *teams* of teachers rather than individual teachers. Second, it guarantees teachers the necessary equipment and materials. Third, it provides local expertise, follow-up sessions and the additional manpower of inservice teachers.

Cooperative Planning Documentation

Teachers, principals and central administrative personnel in seven school districts - Lorain City Schools, Cleveland City Schools, Euclid City Schools, Cleveland Heights City Schools, Maple Heights City Schools, East Cleveland City Schools and Bedford City Schools - have helped in the planning of this grant proposal.

"Citizen Scientists with a Satellite Connection" is also a collaboration between Cleveland State University's College of Education and both the Cuyahoga Valley Environmental Education Center ("CVEEC") and the Ohio Space Grant Consortium ("OSGC"). These two agencies make up the GLOBE "franchise" team conducting the summer workshop.

Table 1 in the appendix lists the sixteen meetings held during the planning stages of this grant proposal.

Needs

"Citizen Scientists with a Satellite Connection" specifically addresses three critical needs:

1. It fosters *content-knowledge-building* for *middle-level* (fourth though eighth grade) preservice and inservice science teachers.
2. It immerses the participants in teaching practices that parallel the national standards including an *inquiry-based approach* and *cooperative learning techniques*.
3. It targets inservice teachers serving primarily *minority* (African American and Hispanic) students from *low-income families*.

Let's substantiate each of these needs in more detail starting with the first one, the need for middle-level science teachers to build content knowledge in the sciences. Nearly all fourth, fifth, and sixth grade teachers teaching science in Ohio and most seventh and eighth grade science teachers as well are elementary certified. Although all elementary-certified teachers are required to have some science courses, the requirement may be as small as 12 semester hours of undergraduate science instruction at the introductory level. Introductory science courses at large universities are typically *not* taught with an inquiry-based approach but rather in a large-audience lecture format (Pew Science Program, 1998). This scanty amount of science instruction may not provide the in-depth understanding and confidence-levels needed to teach science well. Some experts have suggested that the need for staff development in the middle grades is especially critically needed (Killion, 1999; National Staff Development Council, 1997).

The second need being addressed is fostering a change in teaching style that reflects the state and national standards. An assumption that grounds the National Science Education Standards (NSES) is that "students develop an understanding of the natural world when they are actively engaged in scientific inquiry" (National Research Council, 1996, p. 29). This assumption is based on research in learning which suggests that students reach deeper understandings, remember ideas better, and think most incisively when they are self-directed to obtain meaning from what they are learning (Pintrich & DeGrott, 1990; Shuell, 1988; U.S. Department of Education, 1997). Further, the authors of the NSES advocate "authentic questions," "real phenomena," and learning through "social processes" (p. 30). Students, regardless of ethnicity or class, construct their own knowledge socially (Novak, 1985; Strike & Posner, 1985). Hence, "cognitive abilities are socially transmitted, socially constrained, socially nurtured, and socially encouraged" (Day, French, & Hull, 1985).

Finally, the third need being addressed by "Citizen Scientists with a Satellite Connection" is to target teachers of minority students coming from low-income families. These teachers in particular may need to receive professional development opportunities that will help them build their content knowledge and foster a change in teaching style that reflects the state and national standards so as to enhance their teaching of science and math. Ethically, our democratic ideals impel us to make efforts to bring into balance the number of grossly underrepresented minority groups in our science and engineering fields (Massey, 1992). Pragmatically, demographic trends dictate that we induct significantly larger numbers of our minorities into the engineering and science fields because our pool of white males is shrinking (Rutherford and Ahlgren, 1990). Teachers of minority students who have had professional development opportunities to enhance their teaching of science and math can be the catalysts that will close the gap between majority and minority participation in engineering and science fields.

The Third International Mathematics and Science Study (TIMSS) and other research suggests that many U.S. teachers at fourth-eighth grade levels teach science mainly as a vocabulary-building exercise with students working alone answering questions from textbooks and worksheets (Stevenson & Stigler, 1992). A more fruitful way of teaching students, especially minority students, would be to have students working collaboratively in cooperative learning situations (Pintrich & DeGrott, 1990; Shuell, 1988; Slavin, 1996; U.S. Department of Education, 1997). Rather than reading *about* science, students need to engage in actually *doing* hands-on science such as taking measurements and observations, applying science concepts, and analyzing and interpreting data to solve real problems (Helgeson, 1994; Chiapetta & Russell, 1982; Wiley, 1984).

Indicators exist to show that urban minority students in Cleveland and Lorain City Schools may not be learning science well. 1998 school-by-school scores on the science section of the Ohio Proficiency Tests in Lorain and Cuyahoga counties show significant discrepancies between suburban schools with large populations of high socio-economic status families (e.g., Bay Middle School in Bay Village) versus inner-city schools with large populations of minority and low socio-economic status families (e.g., Lorain Middle School in the City of Lorain). "Citizen Scientists with a Satellite Connection" specifically targets middle school teachers of urban minority students in Lorain and Cuyahoga counties.

Goals and Anticipated Outcomes

The main goal and anticipated outcome of this project is that the inservice teacher/participants fully implement the GLOBE program in their classrooms. "Implementation" would include putting into practice authentic learning, cooperative grouping, and inquiry-based pedagogy. Their students would collect, share, and analyze data as a part of GLOBE. Since the workshop cannot occur until summer 2000 and the funding period ends fall 2000, it is anticipated that most teachers will not have had an opportunity to implement all protocols in their classrooms in all of the four areas of atmosphere, hydrology, soil and land cover/biology. It would be more likely that they would have started with one or two areas such as atmosphere and land cover. The implementation of GLOBE is measurable by checking the GLOBE website to see how much data has been entered, by administering a self-report survey and by visiting classrooms to observe and interview both students and teachers.

Activities

The five-day workshop activities will consist of teaching the participants the 20 GLOBE protocols. Best teaching practices including cooperative learning, inquiry-based pedagogy and authentic learning will be used so that teachers will have an experiential model to use in their own classrooms when implementing the GLOBE program for their students. The GLOBE "Teacher's Guide" will be used as the textbook/reference material. Participant evaluation will be a performance-assessment for each of the 20 protocols.

Global Learning and Observations to Benefit the Environment (GLOBE) is a hands-on international environmental science and education program that offers K-12 students the opportunity to become "citizen scientists" and collect data rigorous enough to be useful to scientists and governmental agencies. Protocols used to collect the data integrate life, physical and earth sciences; this program correlates with both the Ohio Science Proficiency Learning Outcomes and National Standards. At the completion of the workshop, teachers will be GLOBE certified to teach their students how to collect data on atmosphere, water, land cover and soil and publish this data on the official GLOBE web site. Training will take place at the Cuyahoga Valley Environmental Education Center in Peninsula, Ohio.

During the workshop, atmosphere protocols will be taught by Ruth Bombaugh and Harley Beall, hydrology protocols by Pamela Barnes and Denise Fluegeman, soil protocols by Linda Box and Mark Pickett, and land cover/biology by Jim Fritzgerald and Charles Bombaugh. Ken DeWitt will be ombudsman. During the times that the franchise team members are not involved teaching their respective protocols, they will assist their fellow members, set-up and take down their own equipment, and serve the program in other capacities as needed. The 50 participants will be divided into two equal groups of 25 each so as to have a smaller participant/instructor ratio (i.e. 12.5 participants per instructor). The following schedule would be for one of the two groups; the other group would be instructed in the same protocols but at a different time and day.

The five-day workshop will start with a half-hour breakfast at 7:45 each morning. On Day 1, registration and an overview of the GLOBE program will last until 10 a.m. followed by a 45-minute introduction to the atmosphere protocols during which participants will practice identifying both the cloud cover and cloud type. Lunch each day will be from 11:45 a.m. – 1p.m. After lunch on Day 1, participants will have a 45-minute introduction to data entry on the Internet. At 1:45 p.m. they will start a 3 1/2-hour session on the atmosphere protocols of air temperature (maximum, minimum and current temperature), calibration of thermometers, and choosing a site for collecting atmosphere data. Dinner each day will be from 5:15 to 6:30 p.m. After dinner on Day 1, participants will practice correct use of the GPS and end with a "Questions and Answers" session at 7:30 p.m.

On Day 2, after the half-hour breakfast, participants will have until 9:45 a.m. to learn how to collect liquid and solid precipitation data and how to find out the pH of precipitation. The remainder of the morning will be spent learning land cover mapping using remote sensing images and MultiSpec software. After lunch, participants will continue with the Land Cover/Biology protocols by practicing species identification using dichotomous keys and by completing two of the learning activities in cooperative groups. Finally, after dinner participants will join together in a "Make-it, Take-it" session to make their own densiometers and clinometers.

On Day 3, participants will use the densiometers and clinometers they made while practicing biometry during the entire morning. Tree circumference and height, canopy and ground cover are the protocols that participants will be completing. After lunch, participants will move into the soil protocols. The afternoon will be spent measuring soil moisture and learning how to make a soil profile. After dinner, participants will select learning activities in soil and participate in them.

On Day 4, participants will finish up the soil protocols in the morning by doing field characterizations (profile color, consistence, structure, texture, slope, particle size, depth pH and carbonates) as well as lab characterizations (fertility, pH, bulk density, and particle size). The afternoon will be spent on hydrology protocols such as water temperature, pH, and dissolved oxygen. After dinner, participants will select hydrology learning activities to complete until the 7:30 question and answer session.

On Day 5, participants will finish the water protocols of alkalinity and electrical conductivity of fresh water in the morning. In the afternoon, participants will have a performance assessment and also spend time brainstorming action plans for implementing the GLOBE program in their schools. Evaluation of the workshop and graduation will be finished by 4 p.m.

Participants will be surveyed before the follow-up sessions to find out which protocols were most problematic to learn. These protocols will be freshly presented for the first hour of each follow-up session. The second hour will be a networking-debrief session and the third hour will be specific pointers on implementation and questions/answers.

Collaborative Structure

The Cuyahoga Valley Environmental Education Center/Ohio Space Grant Consortium GLOBE franchise has the responsibility for recruiting GLOBE schools, training GLOBE teachers and mentoring GLOBE students in the northeast Ohio region. It currently consists of a team of 10 members. Two team members, Ken DeWitt and Mark Pickett, are faculty at the University of Toledo in Chemistry and Engineering, respectively. Ruth Bombaugh of Cleveland

State University is a member of the education faculty. Three other members-- Linda Box, Harley Beall and Pamela Barnes-- are staff at the Cuyahoga Valley Environmental Education Center, and Deborah Yandala is its director. Charles Bombaugh is a registered nurse with a forestry background. Another member, Denise Fluegeman, is a middle-school science teacher deeply involved with the GLOBE program and the final member, Jim Fitzgerald, is a NASA Aerospace Education Specialist at the John H. Glenn Research Center. This ten-member teaching team brings a rich diversity of experiences and expertise to the GLOBE training workshop. The project director, Dr. Bombaugh, for example, is a specialist in middle-school education but also has both a bachelor and master's degree in biology. Harley Beall is a veteran teacher of 32 years but also has been a ranger in the national parks for 24 years. Jim Fitzgerald provides a direct link to NASA's involvement in the GLOBE program.

Teachers, principals and central administrative personnel in seven school districts – Lorain City Schools, Cleveland City Schools, Euclid City Schools, Cleveland Heights City Schools, Maple Heights City Schools, East Cleveland City Schools and Bedford City Schools—have helped in the planning of this grant proposal. The principals of four schools have already committed their buildings and two others have expressed a strong interest.

Appendix Table 1 lists the meetings held with the collaborators of this proposal. The table is offered as evidence of prior project planning.

Participants Involved

Each of the 10 schools will guarantee five participants for a total of 50 inservice teachers and/or administrators. Teachers will be from the middle-school grade levels of fourth through eighth. Four schools have already committed themselves, one each from the Cleveland, Euclid, Bedford and Lorain public-school districts. Six more schools will be recruited. All the schools will serve a majority of underserved and underrepresented students. Some of the schools, Forest Park in Euclid for example, will be sending minority teachers.

In addition to the 50 inservice teachers certified in GLOBE in the summer, 25 preservice teachers will participate in the classroom implementation of GLOBE as a part of their required field-service component of teacher licensure.

Access of Underrepresented and Underserved Groups

"Citizen Scientists with a Satellite Connection" specifically targets teachers in urban schools serving underserved and underrepresented populations of middle school students (grades fourth through eighth). Since the 50 teacher participants will come from only ten schools (five teachers or four teachers and an administrator from each school), Dr. Bombaugh's modus operandi for making sure participating teachers serve underserved and underrepresented groups is to target schools with significant underserved and underrepresented populations. More specifically, the majority of students in the 10 schools chosen to participate will be Hispanic and African-American from low socio-economic families. For example, the Maple Heights school district has an over-all school population that is 63% African American. The particular Maple Heights school, Stafford Elementary, that is committed to participate in this project, however, is currently 93% African American. Also, the principal of Stafford Elementary, Tara Kilburn, and three of the teachers who will be participating are also African American. Orchard Academy in

Cleveland, another of the schools already committed to participate, currently has 97% African American. Whittier Middle School in Lorain is 18% African American and 36% Hispanic. Each of the seven school districts involved with this project has an overall majority of underserved and underrepresented students. A private and/or parochial school will also be sought that has a significant (more than 60%) population of minority students from low socio-economic families.

Evaluation Plan

Quantitative and qualitative components of the summative evaluation will take place early December 2000, nearly six months after the GLOBE training workshop. The evaluation will answer the question: "to what extent has the GLOBE protocols and learning activities been implemented?" The implementation of GLOBE is measurable by checking the GLOBE website to see how much data has been entered, by administering a self-report survey and by visiting classrooms to observe and interview both students and teachers.

The rationale for asking the question "to what extent has the GLOBE protocols and learning activities been implemented?" is the assumption that if GLOBE is well implemented, a positive impact on student learning will occur. This assumption is based on the 2-year GLOBE evaluation independently conducted by the Stanford Research Institute (Center for Technology in Learning of SRI International, 1997). SRI reports: "Both observations of GLOBE students' activities and structured assessment of student knowledge suggest that GLOBE can have a positive impact on students' ability to collect and interpret scientific data in classes where the program is implemented to a significant degree. (Note: SRI conducted a comparative study of GLOBE and non-GLOBE classrooms.) SRI also reported that "GLOBE students appear to make more science-based, higher-level inferences about the natural world than do their non-GLOBE peers." Finally, the report concluded: "the evaluation findings suggest that when well implemented by skilled teachers, GLOBE has a positive impact on students' ability to *do* science and interpret scientific data."

Quantitative data will be gathered from the GLOBE site on the Internet. The archived data will show how often and what kinds of protocols the students were engaged in. A self-report survey to all of the teacher-participants will ask what learning activities they have used, what protocols they have taught in class, and whether their students have done any data analysis or initiated their own research using GLOBE data. The survey will also ask teachers to tell the number of students involved in the protocols, data entry, data interpretation and learning activities. Finally, the evaluator will randomly select two classrooms from two of the schools (a total of four classrooms) to visit and interview both teachers and students.

Replication and Dissemination

Continuation or institutionalization of the project after Eisenhower funding ends will be difficult unless GLOBE changes its policy and allows the franchises to charge a registration fee. Other external funding agencies, however, can and will be sought.

Dissemination of project results to other educators can occur at National Science Teachers Association conferences, the annual GLOBE conference and on the web site. Other opportunities may arise, such as the newly instituted annual American Society of Civil Engineer's National Education Conference.

Budget Explanation

Appendix Table 2 gives a budget summary according to the required categories and line items specified by the Ohio Board of Regents' "Eisenhower Program Proposal Budget Summary." This budget summary was prepared using the "direct costs option" rather than the "regular tuition option." The requested Ohio Board of Regents contribution total $25,944. A line-by-line explanation follows Appendix Table 2.

Appendix Table 3 lists the sources and amounts of the $31,618 matching funds and Appendix Table 4 lists the letters of support submitted by the organizations contributing matching funds. These letters themselves are not included here for the courtesy of brevity. Finally, Appendix Table 5 includes a listing of the 20 protocols along with the instruments and materials necessary to meet the specifications developed by GLOBE scientists to assure consistent and accurate measurements for use by the international environmental science community. A final table in the original grant proposal itemized each equipment purchase and material cost down to the last buffer solution. This table is too cumbersome to put in APA style but is available upon request to the author.

Vitae

Vitae for all 10 members of the Cuyahoga Valley Environmental Education Center/Ohio Space Grant Consortium GLOBE Franchise plus the evaluator were included in the original grant proposal. These vitae included the Principal Investigator, Dr. Bombaugh, the three staff members and director of CVEEC, and the other five consultants assisting in teaching the GLOBE workshop as previously discussed in the collaboration section of this grant proposal. These vitae are available upon request.

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Appendix Table 1:

List of Meetings with Collaborative Partners

Date, Location and Persons Attending

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1. Friday, January 22, 1999 Dr. Bombaugh met a half-hour with Laurie Godfrey, science coordinator and teacher at Lowell Academy of Lorain City Schools ("LCS"). The meeting focused on discussion of LCS's science curriculum in the upper elementary grades (currently defined as middle school, grades 4-6) and potential needs in updating the science curriculum. Meeting held on-site at Lowell Academy, 3200 Clinton Avenue, Lorain, OH.
2. Friday, January 29, 1999 Dr. Bombaugh met forty-five minutes with David Majesty, Director of Academic Services for the Lorain City Schools to discuss the district's plans for a systemic change initiative in its elementary science program and the inclusion of GLOBE in that effort. Meeting held on-site at LCS Charleston Administration Center, 2350 Pole Avenue, Lorain, OH.
3. Saturday, February 6, 1999 Dr. Bombaugh met for three hours with Linda Box, GLOBE coordinator for Cuyahoga Valley Environmental Education Center and other members of the Cuyahoga Valley Environmental Education Center/Ohio Space Grant GLOBE franchise team. Focus of the meeting was workshop design for certifying teachers in GLOBE. Meeting held on-site at the Cuyahoga Valley Environmental Education Center, 3675 Oak Hill Rd, Peninsula, OH.
4. Monday, February 8, 1999 Dr. Bombaugh met an hour individually with Henry Harsar, Principal at Whittier Middle School of LCS and teachers Leonard Ambrosio, Bonita Glasbrenner, and Barbara Uehlein to discuss possibilities of future collaboration with CSU

including implementation of GLOBE. Meeting held on-site at Whittier Middle School, 3201 Seneca Ave, Lorain, OH.

5. Tuesday, February 9, 1999 Dr. Bombaugh met forty-five minutes with Corlista Hardman, teacher and science coordinator of Orchard Academy (Cleveland Public Schools) and teacher Mrs. Pressly and principal Teacola Offutt to discuss needs of upper elementary (middle school grades 4-5) in science curriculum. Meeting held on-site at Orchard Academy, 4200 Bailey Avenue, Cleveland, OH.
6. Friday, February 12, 1999 Dr. Bombaugh met 2 hours with Steve Haines, sixth grade teacher at Hawthorne Academy of LCS and his sixth grade class of students to discuss GLOBE and future collaboration in the implementation of GLOBE. Also met with other Hawthorne teachers, including Arturo Hernandez and Jennifer Hayden, to talk about GLOBE. Meeting held on-site at Hawthorne Academy, 602 West 20 St., Lorain, OH.
7. Tuesday, March 16, 1999 Dr. Bombaugh met an hour and a half with Adam Fender and Michele Micale, teachers at Central Middle School of Euclid City Schools about current science curriculum in place at Central Middle School and the possibility of becoming a GLOBE certified teacher. Meeting held on-site at Central Middle School, 20701 Euclid Ave, Euclid, OH.
8. Saturday, March 20, 1999 Dr. Bombaugh served as volunteer judge for 5 hours at the Cleveland State University "Science Olympiad." The Olympiad involves fourth-sixth graders in 44 public schools in Cuyahoga County. During the "down" times, Dr. Bombaugh talked with teachers and parents about GLOBE.

9. Friday, April 9, 1999 Dr. Bombaugh met four hours with Harley Beall, retired teacher and park ranger of Cuyahoga Valley National Park to coordinate curriculum plans for teaching the atmosphere protocols of GLOBE during proposed teacher workshop.
10. Tuesday, April 13, 1999 Dr. Bombaugh met forty-five minutes with Denine Goolsby, principal of Canterbury School of Cleveland Heights Public Schools. Discussion focused on current program in science and the possibility of GLOBE. Meeting held on-site at Canterbury School, Cleveland Heights, OH.
11. Wednesday, April 14, 1999 Dr. Bombaugh met individually a total of two hours with Henry Harsar, Principal at Whittier Middle School of LCS and teachers Leonard Ambrosio, Bonita Glasbrenner, and Barbara Uehlein to discuss details of the Eisenhower grant proposal, "Citizen Scientists with a Satellite Connection." Meeting held on-site at Whittier M.S., Lorain, OH.
12. Friday, April 16, 1999 Dr. Bombaugh met an hour with Mrs. Smith and Mr. Saywell, teachers at Thomas Jefferson Elementary of Euclid City Schools. Discussion focused on science curriculum and possibility of GLOBE. Meeting held on-site at Thomas Jefferson Elementary, Euclid, OH.
13. Friday, April 16, 1999 Dr. Bombaugh met forty-five minutes with Shirley Washington, principal at Forest Park Elementary of Euclid City Schools. Discussion focused on current science curriculum and possibility of GLOBE. Meeting held on-site at Forest Park Elementary, Euclid, OH.
14. Saturday, April 17, 1999 Dr. Bombaugh met three hours with Linda Box, GLOBE coordinator for Cuyahoga Valley Environmental Education Center and other members of the Cuyahoga Valley Environmental Education Center/Ohio Space Grant GLOBE franchise

team. Focus of the meeting was workshop design for certifying teachers in GLOBE. Meeting held on-site at the Cuyahoga Valley Environmental Education Center, 3675 Oak Hill Rd, Peninsula, OH.

15. Tuesday, April 20, 1999 Dr. Bombaugh met an hour and a half individually with Ms. Poole, teacher, and Tara Kilburn, principal of Stafford Elementary of Maple Heights City Schools. Discussion focused on perceived needs for systemic change in the science curriculum and GLOBE. Meeting held on-site at Stafford Elementary, Maple Heights, OH.
16. Wednesday, April 21, 1999 Dr. Bombaugh met an hour with Teacola Offutt, principal of Orchard Academy of Cleveland Public Schools as well as teachers Lyn Jefferys and Agnes Pressly about the details of the Eisenhower grant proposal, "Citizen Scientists with a Satellite Connection." Also served two hours as volunteer science fair judge for the annual science fair. Meeting and science fair held on-site at Orchard Academy, 4200 Bailey Avenue, Cleveland, OH.

Appendix Table 2

Summary of Eisenhower Program Proposal Budget - "Direct Costs Option"

Category and Name of Line Item	Eisenhower	Other
1. Personnel Costs		
A. Salary of Principal Investigator	$5,700	$2,154
Total Personnel Costs (Add Salaries and Fringe Benefits)	$5,700	$2,154
2. Contractual (Consultants, Other Subcontracts)		
A.CVEEC	$8,728	$3,385
B. Franchise Team	$3,000	$2,000
C. Evaluator	$500	
3. Participant Costs		
A. Tuition and Fees		
B. Room and Board		$7,500
C. Travel		$640
Total Participant Costs		$8140
4. Other Travel		
5. Supplies and Materials		
A. Books		$5,000
B. Instructional Materials	$20	
C. Other (Identify) - Lab materials (perishable)	$3088	
6. Equipment (Rental, Purchase)		
A. Lab Equipment (non-perishable)	$2392	$10,4000

7. Communications		
8. Services (Duplication, Publication, Etc.)		
A. Duplicating	$55	
9. Other Costs		
10. Subtotal Costs (Sum of Items 1-9)	$24,023	$31,618
11. Indirect Costs (8% of Subtotal Costs)	$1,921	
12. Total Costs (Sum of Items 10-11)	$25,944	
13. Total Requested Eisenhower Funds	$25,944	

Explanation of the Budget Line-by-Line of Appendix Table 2:

Item #1 "Personnel Costs" consist of the project director's, Dr. Bombaugh's, imput of time. Dr. Bombaugh anticipates spending 30 hours of meeting with administrators and teachers to recruit the remaining six schools, 12 hours to prepare the workshop schedule and other handouts necessary, 24 hours (4 meetings/6 hours) for planning with the franchise team, 8 hours for logistics, 5 hours for set-up time and 48 hours of contact time during the summer workshop, 40 hours of field-work working with teachers during the implementation of the program, 5 hours of planning for the two follow-up sessions, and 6 hours of contact time during the follow-up sessions. This totals 178 hours. Item #A1, "Salary," is made up of a $3600 OBOR contribution and $2154 CSU (SIP department) contribution to release Dr. Bombaugh from one class spring semester plus a $1500 OBOR contribution for summer salary during the workshop. Item #A2, "Fringe Benefits" is calculated at the CSU rate of 25% during the academic year and 16% during summer. OBOR funds would contribute $1140 and CSU would contribute matching funds of $539.

Item #2, “Contractual,” has three components: cost of facilities and staff help from Cuyahoga Valley Environmental Education Center (“CVEEC”), hiring the GLOBE franchise team as consultants to aid in teaching the workshop, and hiring an evaluation consultant. Item #2A, “CVEEC” is made up of facility costs (total $2,590 which breaks down to the five-day workshop rental for the newly-built, beautiful “November Lodge Legacy Room” at $250/day, the White Pines Meeting Room at $120/day, the White Pines Lab at $50/day, the Lipscomb Lab at $50/day and 8 hours of computer usage at $30/hour) and personnel costs. Three staff members (Linda Box, Pamela Barnes, Harley Beale) and the director (Debra Yandala) will be donating a total of 154.5 hours (making up the $3,385 contribution of “other” listed in item #2A, “CVEEC”) and charge OBOR $6,138 for another 330.5 hours of work during the summer workshop.

Item #2B, “Franchise team,” has two consultants – Jim Fitgerald, NASA Aerospace Education Specialist, and Ken DeWitt, University of Toledo Professor and Director of the Ohio Space Grant Consortium – who are not charging for their time to teach the summer workshop. (That’s the $2000 contribution of “other.”) Three other franchise team consultants – Denise Fluegeman, Marcia Fetters, and Mark Pickett – are charging OBOR $3000 for their combined 132 hours of workshop teaching.

Item #2C, “Evaluator,” is $500 of OBOR funds to hire an outside evaluator.

Item #3B, “Participant Costs, Room and Board” has a $7,500 contribution from participating schools to pay $150/participant for the meal fee. Item #3C, “Participant Costs, Travel,” is calculated at the federal rate of $0.325/mile for participants to attend the two follow-up sessions. This $640 cost is also being borne by the participating schools.

Item #5A, “Supplies/Materials, Books,” has $5,000 worth of Teacher Guides contributed by GLOBE for each of the 50 summer workshop participants. (Each guide that each participant receives is valued at $100.) Item #5B, "Instructional Materials," is a $20 cost borne by OBOR for overhead projector transparencies and markers. Item #5C, "Lab materials" are perishable items used in the GLOBE protocols such as calibrating solutions, dissolved oxygen kits etc. (Please see Appendix C, "Budget Detail for an exact accounting.")

$12,792 worth of equipment added to the $3088 worth of materials (total of $1,540 per school) will provide teachers the necessary means to implement GLOBE. Item#6A shows that OBOR will contribute $2392 towards equipment. #5000 more will be contributed by the schools, $400 by the Ohio Space Grant Consortium ("OSGC"), and the final $5000 will be contributed by CSU through its Martha Holden Jennings Foundation's Grant, "University Partnership – Urban Initiative."

Finally, Item #8A is $55 to help defray duplicating costs for the "Networking Notebooks" that will contain participant phone numbers, email addresses, GLOBE point of contacts and other highly useful information that the participants will take home with them.

Appendix Table 3

List of Sources for Matching Funds with the Amount Committed by Each Source

Name of Sources	Amount
Participating Schools and School Districts (Meal fees and Mileage)	$8,140
Participating Schools and School Districts (Equipment Cost)	$5,000
GLOBE (Teacher's Guides, Cloud Charts and Dichotomous Keys)	$5,000
Martha Holden Jennings Foundation Grant (Equipment Cost)	$5,000
Cuyahoga Valley Environmental Education Center (Personnel Cost)	$3,385
Cleveland State University (Personnel Cost)	$2,693
Franchise Team Members (Contractual Cost)	$2,000
Ohio Space Grant consortium (Equipment Cost)	$ 400
Total Contributions from non-Eisenhower Sources	$31,618

Appendix Table 4

List of Supporting Letters Included with Original Eisenhower Proposal

Name of Person and Organization or Institution
Deb Yandala, Director, Cuyahoga Valley Environmental Education Center
Ken DeWitt, Director, Ohio Space Grant Consortium
James McLoughlin, Dean of the College of Education, Cleveland State University
Tom Pyke, Director, The GLOBE Program
Dave Majesty, Director of Academic Services, Lorain City Schools
Nylajean McDaniel, Ph.D., Director of C&I, East Cleveland City Schools
Tara Kilburn, Principal, Stafford Elementary School, Maple Heights City Schools
Henry Harsar, Principal, Whittier Middle School, Lorain City Schools
Shirley Washington, Principal, Forest Park Elementary School, Euclid City Schools
Teacola Offutt, Principal, Orchard Elementary School, Cleveland City Schools
Lynn Jefferys, Teacher, Orchard Elementary School, Cleveland City Schools
Martha Burrows, Preservice Teacher, Lowell Academy, Lorain City Schools
Stephanie Moss, Preservice Teacher and Cleveland Heights City Schools Parent
Katia Karim, Preservice Teacher, Orchard Elementary School, Cleveland Public Schools

Appendix Table 5

Instruments, Equipment and Materials for the 20 GLOBE Measurements

Area of Study	Measurement	Instrument, Equipment, or Material
Atmosphere		
	Cloud Cover and Type	Cloud chart
	Air Temperature	Wooden, white instrument shelter
		Maximum/minimum thermometer
		Calibration Thermometer
	Precipitation, Liquid	Rain gauge
	Precipitation, Solid	Snow board (student made)
		Rain gauge
		Snow depth pole (student made)
	Precipitation pH	pH meter
		Buffer solutions - pH 4, 7, &10
Hydrology		
	Water Temperature	Calibration thermometer
	Water pH	pH meter
		Buffer solutions - pH 4, 7, &10
	Dissolved Oxygen	Dissolved oxygen kit
	Alkalinity	Water alkalinity kit
	Electrical Conductivity	Conductivity meter
		Calibration solution for meter

	Nitrate	Water nitrate kit
	Transparency	Turbidity tube (student made)
Land Cover		
	Land Cover Mapping	Remote sensing image
		Multispec software (free on internet)
	Species Identification	Dichotomous Keys (from GLOBE)
	Biometry including:	50 - meter tape measure
		Disposable camera with film
		Suunto Compass
		Bundle of 25 stake flags
	a. Three Circumference and Ht.	Clinometer (student made)
	b. Canopy/Ground Cover	Densiometer (student made)
Soil		
	Moisture	Balance
		Meter stick
		Drying oven - soil
		Dutch Auger
		50 - meter tape measure
		Soil sample containers
	Field Characterization including:	Camera
	a. Profile Color	Color chart
	b. Consistence	(Students only use sense of vision)

	c. Structure	(Students only use sense of touch)
	d. Texture	(Students only use sense of touch)
	e. Slope	Meter stick and clinometer
	f. Depth pH	pH meter and buffer solutions
	g. Free Carbonates	Distilled white vinegar Acid drop bottles
	h. Presence of Roots	(Students only use sense of vision)
	Lab Characterization including:	
	a. Fertility	Soil NPK kit
	b. pH	pH meter and buffer solutions
	c. Bulk Density	Drying oven - soil #10 sieve (2 mm mesh) Balance Soil sample containers
	d. Particle Size	Graduated cylinder, 500 ml Dispersing solution Thermometer, smooth sided Hydrometer
	Infiltration	Dual ring infiltrometer (homemade)
	Soil Temperature	Soil thermometer
Location	Latitude and Longitude	Global Positioning System receiver

ENHANCING SCIENCE EDUCATION PRESERVICE AND INSERVICE TEACHER PROFESSIONAL DEVELOPMENT USING GLOBE ENVIRONMENTAL SCIENCE CURRICULA

Linda K. Ramey, State University
James Tomlin, State University

> *Modern industrial civilization, as presently organized, is colliding, violently with our planet's ecological system. The ferocity of its assault on the earth is breathtaking, and the horrific consequences are occurring so quickly as to defy our capacity to recognize them, comprehend their global implications, and organize an appropriate and timely response (p. 269, Gore, 1993).*

Environmental science education (ESE) addresses the need for a more integrated approach to science learning about the natural world as well as fostering creative and realistic problem solving skills. ESE, being an integration of several disciplines, lends itself to open-ended investigation and to teaching science concepts in a connected, meaningful manner. The integrated nature of ESE also readily lends itself to teaching and learning in a multitude of subject areas, in using a thematic approach, and drawing upon multiple intelligences (Gardner 1983; 1993) and varied learning styles of students and teachers alike. Another benefit of a sound ESE curricular emphasis in schools is the inclusive nature of this type of hands-on science investigation--as stated repeatedly in the science education reform literature--science needs to be for all students. This is by virtue of the attributes of ESE, a greater number of students are reached and actively involved in environmental science learning.

The WSU GLOBE Project

There is the need for direct, strong connections linking science as it is taught as classroom curriculum with environmental outdoor field trips, and assessment such as the Ohio Science Proficiency Outcomes testing. Several Ohio Science Proficiency Outcomes test questions refer to environmental science concepts, such as renewable versus nonrenewable resources, and the dynamics of food webs. Within such contexts, students are expected to analyze and interpret data and think critically about the information presented. Quality ESE programs bring sound understanding of environmental concepts into day to day classroom teaching by including meaningful integration of science, mathematics and technology, with other areas of learning. Long term investigations, such as those in the Global Learning and Observation to Benefit the Environment (GLOBE) program (Finarelli, 1998), allow students to be actively involved in data collection, analysis of data, and use of graphic representation of data, leading to better understanding of scientific process and methods while gaining understanding of environmental parameters and issues. Teachers and their students benefit from far-reaching programs like GLOBE in that inclusion in this network helps them to develop conceptual understanding of environmental issues and to sharpen critical thinking and problem-solving skills.

Involvement in projects such as The Southern Ohio GLOBE Environmental Science Education Initiative (SOGESEI) fosters an awareness and understanding of environmental issues first on a local, more immediate scale, then on a more global, ecological level. This approach to learning increases the likelihood of student involvement in a proactive, solution-oriented approach to conservation and preservation of earth's natural resources. The Wright State University (WSU) SOGESEI science education program provides an in-depth understanding of the global nature and complexity of environmental issues. The GLOBE protocols and curricular materials bring content and procedural knowledge of environmental scientific protocols for atmospheric/climate, land cover, hydrology, and soils data collection and internet data reporting into the K-12 classroom setting. This data is entered and compiled with the existing GLOBE data from over 4,000 GLOBE school sites throughout the U. S. and 62 other countries worldwide. This collaborative project draws together resources and expertise of several key environmental educators and institutions in the southern Ohio area. Project facilitators brought complementary areas of expertise to the summer institute, providing teacher training in a variety of environmental protocol areas, acting as a resource for the various research investigations, and assisting the teacher participants in establishing their GLOBE school site, and implementing data collection and use in classrooms.

The primary objective of WSU SOGESEI project has been to provide 28 classroom teachers with the necessary in-depth background and understanding of critical environmental issues coupled with the scientific knowledge to conduct GLOBE protocol data collection and recording with their students. Through inquiry-based science education lessons and long term investigations appropriate for their grade level, teacher participants have used these experiences to translate and extend their students' understanding of the complexity of environmental ecology. High quality interactive presentation of curricula and materials, such as the GLOBE program, coupled with year long support and follow-up is a proven model for teacher professional development for implementing change in science education (Ramey-Gassert, Shroyer, Staver, 1996).

Teacher teams from schools throughout Ohio were selected to participate in this project. They received GLOBE material kits containing the necessary equipment to conduct classroom-based environmental research and data collection, attended a one-week institute, and will attend follow-up meetings periodically throughout the academic year for additional professional development. In addition, each participant has had site visits to their schools to assist with the implementation of the program and for additional support throughout the year.

Connecting Course Development and Teacher Professional Development

In an effort to help teachers construct the pedagogical skills, curriculum knowledge, and attitudes and dispositions necessary to educate all students, university and/or site-based courses and partner school inservice programs such as Project Discovery and SOGESEI have been constructed to exemplify good science and mathematics teaching. These courses teach the content, model exemplary pedagogy that the recent science education standards state are necessary to create valuable and practical learning episodes to support excellence and equity for precollege students. Moreover, student understandings are acquired within an active and constructivist, inquiry-based framework designed to enable students to witness science and science education faculty "walking the walk and not just talking the talk".

Working with both preservice and now inservice teachers in our science courses creates greater potential for blending science education theory with effective teaching practices in the classroom, benefiting students and teachers alike. Presently we are exploring ways to match the preservice teachers' field experiences--from the initial early observational phase, to internships/student teaching--with inservice teachers who have been immersed in our expanded science course offerings.

Six new courses are currently being designed for middle level education majors with a concentration in science in response to the new middle level licensure law in Ohio and to the learned society recommendations for middle level science educator preparation. These new courses will provide additional experience in each discipline, as well as, an opportunity for extended integrated ESE investigations. These additional courses will aid in meeting the needs of our preservice teachers not only in middle level content knowledge, but also in implementing the teaching practices modeled in these courses and recommended by the standards.

Bringing Preservice and Inservice Teachers Together

Much of the feedback concerning our science education sequence comes from students during their student teaching experience. One impact that has been noted is the wide-ranging use of hands-on materials and inquiry-based lesson plans developed in the science content courses and science methods courses. This use of materials and lesson plans by our students is impacting K-12 students in classrooms, as well as the cooperating teachers. The inservice teachers ask student teachers for copies of lesson plans and/or where they can obtain the materials. With this, inservice teachers learn about the university science education program as they see how a constructivist approach to science teaching works with their class. This, of course, benefits K-12 students, preservice, and inservice teachers by reinforcing a constructivist, inquiry-based approach to science teaching in a learning environment.

Another result of both pre- and inservice science education programs has been the recruitment of efficacious inservice teachers to teach site-based science methods courses in partnership schools. The sequence of the programs has been designed to systematically provide science education experiences that build knowledge and understanding of constructivist science teaching principles and pedagogy for preservice and inservice teachers while expanding the learning experience to impact the classrooms in the region. With a cadre of teachers, both the graduate preservice teachers and other inservice teachers who have attended science professional development programs, we are beginning to see the positive impacts. Evidence of this is apparent in the constructivist science teaching by student teachers as well as with classroom teachers who are adjunct instructors for our science methods courses. Both of these groups have witnessed the positive learning outcomes of inquiry-based science teaching with K-12 students.

The following quotes provide evidence of one such placement where a student teacher was placed with an inservice teacher who adopted a constructivist approach to teaching following her participation in several Project Discovery professional development science and mathematics courses in our program.

> Student Teacher: As I embarked on my student teaching assignment, I was anxious but leery to implement techniques I had learned in my undergraduate studies. I had the fortunate opportunity to work with an energetic, hands-on; inquiry based teacher who paved the way for me to successfully apply my college education. From the first day of school, she instilled in her students the fact that she was not the "giver of information." She was the facilitator. She modeled for me, with her class of 5th graders, what I had only seen modeled on college students. It was proof positive for me that what I had learned at WSU actually worked in the real world. With the stage set by my cooperating teacher, my job was easy. I successfully implemented lessons using the discovery method of learning.
>
> Teacher: Building a constructivist classroom means a change in attitude about my role as a teacher. For years I have been taught that the teacher should be the facilitator of learning, not the transmitter of knowledge, yet I fell into the trap of believing that because I did lots of hands-on activities with my class, I was a true facilitator. It never occurred to me that doing a demonstration, reading the chapter and doing a "neat" activity wasn't really changing my role.
>
> Teacher: A constructivist classroom recognizes the importance of activities that help students interpret the "real" world. This kind of learning can only take place in a natural environment where students are allowed to experience the process of inquiry. One of the most valuable things I learned during my work in Project Discovery is the power of having living organisms in my room. Over the years I have rarely had classroom pets (I am a city girl) and never used them for any learning activities. I now have a menagerie of organisms from leeches to rabbits and am amazed at what is happening in my classroom. Students have learned to respect living creatures in a way I would have never thought possible. In addition, they have learned responsibility in caring for the animals. (Each animal station requires feeding, cleaning, or some other task. A team of students is responsible for each station.) Students are seeing the food chain in action and are designing experiments to learn new information about the animals. The time that students spend is worth it.

A Final Comment

As we continue our program development and modification our science courses to allow classroom teachers opportunities to learn content while updating their understanding of science education pedagogy, one continuing concern is staffing these courses. The challenge is to find faculty who are knowledgeable in inquiry and cooperative learning strategies, as well as, having an in-depth science content understanding to confidently handle the open environment of the constructivist classroom. This staffing concern has already arisen in maintaining the core courses and has been partially addressed by utilizing inservice Master teachers, like the one quoted herein, as faculty. These teachers all have had substantive professional development experiences in science that were sustained for at least one year, emphasized standards-based curricula and enhancement of content knowledge, and provided in-depth coverage of science content while modeling inquiry, problem-solving, and cooperative grouping techniques. These Master teachers bring not only their deep content and pedagogical knowledge to the preservice teachers, but also their rich classroom experience. As discussed above, the science education, and the middle level program in particular, continues to evolve and grow while enriching the teaching and learning of preservice as well as inservice teachers in area schools.

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PRE-SERVICE SECONDARY SCIENCE TEACHERS' CONCERNS REGARDING USE OF CALCULATOR-BASED LABORATORY SCIENTIFIC PROBEWARE

David R. Wetzel, Muskingum College
Gary F. Varrella, George Mason University

Learning to apply instructional technologies effectively poses a significant challenge to pre-service teachers as they prepare to enter their science teaching career. Application and integration of instructional technology into daily routines present additional demands and technical skills beyond those found in many pre-service programs. Among the many computer-based instructional technology tools, there is one tool called Calculator-Based Laboratory (CBL) probeware. Traditionally operation, application, and integration of CBL probeware is not taught in pre-service instructional technology oriented courses. Such courses ordinarily focus on multimedia, computer skills, and applications (Knapp & Glenn, 1996). In response to this dilemma, George Mason University's pre-service science teacher preparation program began providing hands-on experience with CBL probeware in secondary science methods courses.

The integration of CBL probeware is increasing in science classrooms as schools and school systems find this technology to be an economical real time data collection tool for their students (Virginia Department of Education (VDOE), 1997). The use of this and other technologies in science is advocated by the *National Science Education Standards* (National Research Council (NRC), 1996) and the *National Education Technology Standards* (International Society for Technology in Education (ISTE), 1998). The *National Education Technology Standards* specifically recommends the use of scientific probeware with students when conducting real time investigations of natural scientific phenomena. The use of this technology supports the shift from conventional teacher/student dialogue and teacher-centered instruction to a learning environment that is student-centered and inquiry-based (NRC, 1996; ISTE, 1998; Zuga, 1991).

This is a study of how 14 pre-service teachers grew over a period of two consecutive semesters as CBL probeware was integrated in their course requirements. The integration of CBL probeware was to meet the need for their technical and pedagogical expertise with this instructional technology tool (VDOE, 1997). As a measure of growth among the participating pre-service students, a questionnaire was administered using a quasi-experimental design (Creswell, 1994, p. 133). Data were gathered before and after the pre-service students' experiences and study of CBL probeware materials and application.

Population and Procedures

This study involved 14 pre-service science teachers enrolled in two science methods courses during consecutive spring and summer semesters. During the first methods series, the pre-service teachers were provided with three hours of experience in basic operation and integration techniques of CBL probeware. Students were also required to practice integration of CBL probeware into a model, theme-based week long curriculum "module." During the second methods course, the pre-service teachers where engaged in an additional ten hours of field based, advanced operation and integration of techniques of CBL probeware within content-specific curricula (e.g., earth science, chemistry, biology, and physics) with science teachers in actual school science classrooms. The pre-service teachers' spent and additional five hours of field based experience using other instructional technology tools (e.g., imaging, web-based research, and interactive software). As part of the requirements during the second course, students developed a four-week unit plan that integrated CBL probeware and other instructional technologies into their curriculum design (Based on a design by Donna Sterling, George Mason University).

Methodology

The pre-service science teachers were administered the same questionnaire (Appendix A) pre-study in February 1999 and post-study in July 1999. This was to measure their growth and confidence after these two experiences to explore their concerns regarding CBL probeware. Administration of the questionnaire during the spring methods course was prior to the introduction and hands-on experiences with CBL probeware. The second administration of the questionnaire was near the end of the summer methods course. The questionnaire was a modified version of the Stages of Concern Questionnaire for an innovation (Hall, Loucks, Rutherford, & Newlove, 1975). The questionnaire contained 24 statements to assess the pre-service participants' level of concerns related to the integration of CBL probeware technology into their teaching routines. All 24 response items employed a Likert Scale ranging from "strongly agree" to "strongly disagree" and included a selection of "not applicable." Two additional open-ended questions allowed the students to express their own views regarding the use of CBL probeware. The 24 statements of concern in the questionnaire focused on four categories of concern; 1) technical knowledge, 2) pedagogy, 3) classroom management, and 4) collaboration. Validity and reliability of the questionnaire was accomplished through analysis of questionnaire items with non-participants of the study for clarity and design.

Analysis

Analysis of data consisted of a paired t-test that was performed for each category, along with a paired t-test for a combining of all categories in each administration of the questionnaire.

This analysis was accomplished by using the Statistical Package for the Social Sciences (SPSS). An alpha level was set at $p = < .05$. In addition, the results of the two open-ended pre- and post-study questionnaire questions were analyzed for comparison of common concerns regarding how the pre-service teachers felt that CBL probeware should be used. Barriers to and support of their learning experience related to the use of this technology were addressed as well. Findings of the four categories of concern; technical knowledge, pedagogy, classroom management, and collaboration emerged upon analysis of the 24 statements. Figure 1 provides an overview of the shift in student concerns when using CBL probeware.

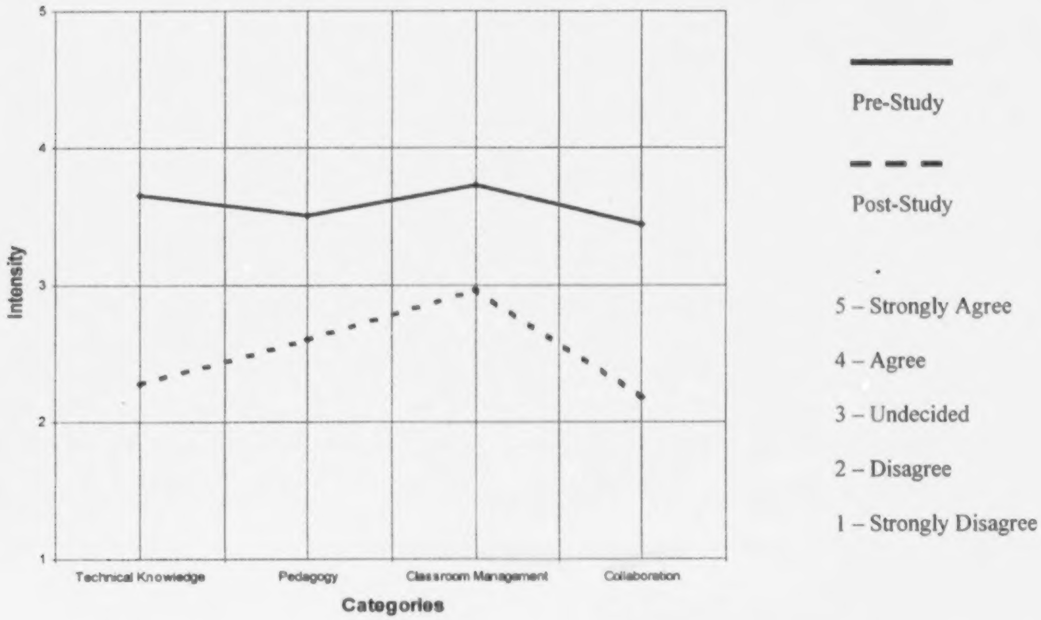

Figure 1. Intensity of concerns by category.

Findings

The findings of the four categories are summarized in Table 1. Results showed an overall significant decrease ($p = .001$) in level of concerns by the pre-service teachers regarding the use of CBL probeware between the pre- and post-study questionnaire. The results of these pre-service students' levels of concern regarding technical knowledge ($p = .002$), pedagogy ($p = .026$), and collaboration ($p = .003$) also shared a significant decrease. There was no significant decrease of concerns in the management category. The written reflective comments of the pre-service teachers in response to the two open-ended questions added further evidence of the overall decrease of their levels of concerns regarding the integration of CBL probeware.

Table 1 reveals that after the pre-service students' experience of learning how to operate and integration of CBL probeware, the pre-service teachers had developed enough technical knowledge to significantly reduce their intensity of concerns. The participants' experience working with their peers and inservice teachers appear to have been a significant influence on their growth and abilities. This growth resulted in a significant reduction in their concerns regarding collaboration with peers. Even though there was a significant overall decrease in their concerns, there was a not a significant shift in concerns regarding classroom management. Figure 1 presents the pre- and post-study mean scores for each category.

Technical Knowledge

Results indicate a significant decrease in the pre-service science teachers' concerns regarding their technical knowledge with CBL probeware. This category is based on their knowledge to operate and integrate this technology, confidence in their abilities, and ability to

Table 1.

Paired Samples T-Test (N =14)

	Mean	SD	t-value	Df	Sig.
Technical Knowledge	1.3733	.5873	5.728	5	.002*
Pedagogy	1.2983	1/0163	3.129	5	.026*
Classroom Management	3.7683	.7693	2.447	5	.058
Collaboration	1.2783	.5639	5.553	5	.003*
Combined Categories	1.1796	.7466	7.740	23	.001*

Note. $p < .05$

operate and integrate related resources. One significant finding in their technical knowledge was their lack of concern regarding their pedagogy. Their level of technical expertise will allow them to overcome their concerns that their students have a greater technical expertise regarding the technical aspects of CBL probeware than the participants. This is an opposing view compared to other inservice teachers, who are concerned that their students have a greater technical ability with CBL probeware (U. S. Congress, Office of Technology Assessment, 1995; Wetzel, 1999).

Figure 1 reveals that the participants' mean response is in agreement regarding their concerns with their technical knowledge in the pre-study administration of the questionnaire. When given the post-study questionnaire, their mean reaction to the 24 statements of concern was that they are concerned with their technical technology. The courses' goals of introduction and application in the spring semester, with follow-on application and hands-on experiences with practicing teachers in the summer session appears to have achieved the desired treatment. There was a significant reduction in the participants' intensity of concerns regarding their technical knowledge regarding CBL probeware, with a shift in mean from 3.65 to 2.27.

Pedagogy

Results indicate there was a significant decrease in the pre-service science teachers' concerns regarding their pedagogy when teaching with CBL probeware. This category is based on their concerns regarding use with students and the affect of their teaching on students' learning science. Figure 1 reveals that the participants are mostly undecided with their concerns integrating CBL probeware and their pedagogy. This finding reflects that the courses' significantly influenced a shift in their concerns regarding pedagogy, the mean shift was from 3.50 to 2.55. Additional preparation with grades 6-12 students may achieve a greater shift in their concerns.

Classroom Management

Results indicate there was not a significant decrease in the pre-service science teachers' concerns regarding their classroom management when teaching with CBL probeware. This category is based on their concerns in their future role as a teacher, their future students' role, how to effectively manage students when integrating this technology in laboratory investigations, time management for further development of their technological skills, and time for implementing and integrating this technology in their curricula. Figure 1 reveals that the participants' had a slight shift in their intensity of concerns regarding classroom management. This shift, 3.70 to 2.96, was from a mean in agreement with concerns to a position of being undecided regarding their classroom management abilities. This finding was not unexpected in that they have had little practical classroom application with students. This category requires additional preparation with grades 6-12 students.

Collaboration

Results indicate there was a significant decrease in the participants' concerns regarding their collaboration with other pre-service teachers and inservice teachers. This category is based on the participants sharing their knowledge and experiences with other pre-service and inservice teachers. Figure 1 reveals that the pre-service teachers shifted from a position that was somewhat in agreement regarding concerns to a position that disagrees with being concerned.

This shift in mean, 3.44 to 2.17, can be largely attributed to the instructional methodology, providing the participants with the opportunity to develop their technical knowledge and curricula integration techniques with CBL probeware over a span of two semesters. An additional finding, beyond studying levels of concern as an indicator of growth and program efficacy, was the powerful effect of the technically proficient practicing teachers on the participants as part of their developmental experience. Based on the post-study questionnaire results, their hands-on experience with practicing classroom science teachers in an actual school environment appears to have been a significant key in the decrease in the intensity of concerns by the pre-service teachers.

Open-ended Questions

The two open-ended questions were designed to elicit reflective responses from the participants that were not measured in the 24 statements of the questionnaire. The first question was based on how they would employ CBL probeware in their science classroom? In the pre-study administration of the questionnaire their responses ranged from not having any idea what CBL probeware was to having heard of the technology, although the pre-service teachers were not sure of CBL probeware. Examples of these responses included:

- "I have absolutely no idea what CBL probeware is, let alone how to use it."

- "I have never used CBL probeware so I can't readily say specifically how I would use it."
- "I have heard of it, but I'm not sure."

After completing the two courses, responses in the post-study questionnaire changed significantly. Examples of student responses included:

- "As an additional tool in the science toolbox for instructional technology."
- "I plan to use CBL probeware to allow my students to perform/design experiments that they may have not been able to do without CBL probeware, and perform and design more analysis and higher-order/critical thinking."
- "Primarily as data collection and analysis tool. It really shouldn't be used just for the thrill of using technology, but rather to facilitate teaching and learning."

The second question addressed concerns regarding factors that would support and hinder their use of CBL probeware in their classroom? Most responses by participants were similar to responses to question one in the pre-study. Examples of responses that were not similar to question one included:

- "If the tool is limited, then my decision to use it will be limited. If it offers wide possibilities to enhance learning and increase student understanding, ownership, and motivation then I will integrate it into my curriculum."
- "My knowledge of how to operate the CBL probeware will be a critical element."

In the post-study questionnaire their responses provided a picture of a shift in their position regarding question two. Their responses reflected a level of technical knowledge, with their largest concern appearing to be classroom management. Examples of their responses include:

- "Large class sizes, classroom management, and my skill level I think are the main factors in using CBL probeware as a practice in my classroom."
- "Ensuring that CBL probeware is appropriate for chemistry."
- "Time to integrate it within my lessons and class size."
- "Not having enough equipment and resources and class size."
- "Lack of support or help from other teachers."

The participants' responses to the two open-ended questions corroborate the findings of the 24 statements in the questionnaire. Their responses to the two open ended questions reflect a decrease in their intensity of concerns, due to an increase in their level of expertise. This appears to be especially true in the categories of technical knowledge, pedagogy, and collaboration. Overall there was a significant increase in their growth and confidence regarding CBL probeware, as evidenced by the findings of the questionnaire.

Discussion

For the most part, the use of instructional technology in science education is almost like two ships that pass in night. They silently pass without communicating with each other or about their relationship since they have evolved into two different cultures, technology education and science education. In fact, they have grown apart due to their specialization (Lux, 1984). The cultural environment of technology and science teachers perpetuates this artificial separation of technology and science for their students. This artificially and human created separation has not gone unnoticed, however. Philosophers and educators such as Dewey (1925), Whitehead (1925), and Snow (1959) recognized the error of this path and often argued against, particularly from an educational point of view, the separation of technology and science. Today we are still faced with these same difficulties that science teachers have faced for decades, transcending the boundaries of technology and science. This artificial separation leaves us all with an incomplete and less sophisticated understanding of interrelationships and functioning of technology and science (Zuga, 1991; Bauer, 1990).

The use of instructional technology in schools is a fact of life in American education. For students, the ability to use technology has been recognized as an essential skill by society. Recognizing the responsibility to prepare students to work and live in a technological society, national education standards have recommended the use of technology in teaching science. These standards include the *National Science Education Standards* (NRC, 1996) and *National Education Technology Standards for Students* (ISTE, 1998). These standards advocate the use of technology to encourage students to become active participants in the learning process and using the standard methodology used by scientists that include the use of technology. For example, using a CBL Probeware System to collect real time data, organizing sets of data, and analyzing graphs of complex data, etc. (ISTE, 1998; Bowman & Davis, 1997; U. S. Congress, Office of Technology Assessment, 1995).

Instructional technology and science may be expressed in basic terms of technology being viewed as a human endeavor to modify one's environment and science as a human endeavor to explain one's environment (Lux, 1984). Each is a human activity, directed by humans to fulfill our needs and wants; therefore, we control technology and science. The distinction is made merely as a means of distinguishing the role of each in a complex pattern of relationships. Whether we chose to modify our environment lightly or alter it radically in order to live within it, technology is a fundamental value society has chosen (Ihde, 1990).

The separation of technology and science for purposes of study and the tendency to blur the distinctions between technology and science by practice is evident in our school curricula.

We have created separate curricula of technology and science education that are on unequal footing. More over, we have created an unrealistic representation of the role of technology and science in our society and the relationships between technology and science (Zuga, 1991).

The artificial separation of technology and science for the purposes of analysis and study does not exist in real world application. The relationship between technology and science has always been symbiotic, both efforts are necessary for advancement of knowledge in human endeavor (Kranzberg, 1991). Today, the relationships between the activities of scientists and technologists are being established and modified faster than science teachers can identify and describe them. The key concern for these teachers is how to best unify the teaching of science and technology. Science education literature is filled with the call for integration of these two subjects, but the execution has not been widespread (Bybee, 1991; Hurd, 1991; Rubba, 1991; American Association for the Advancement of Science, 1989).

On the other hand, the science education community has had the greatest experience with integrating instructional technology and science compared to other content areas (Bybee, 1991). Yet, sustained integration of technology in science education has been not been achieved. Based on his research, Rubba (1991) argues that teachers with no background and experience in technology cannot be expected to successfully implement technology in their science teaching pedagogy. Because of these factors, it is very difficult for science teachers to overcome their own culture and experience to implement and integrate the use of instructional technology.

Calculator-Based Laboratory Probeware

Figure 2 provides a graphic presentation of a CBL probeware system that is composed of electronic sensor probes, a CBL data collecting device called the CBL system, and a graphing calculator. Sensor probes are used to electronically collect real-time data, such as temperature, motion, voltage, light, sound, etc. The CBL data-collecting system executes the program data collection rate and number of samples to be taken. The graphing calculator has two purposes; allows operation of the program that controls the CBL data collection system and stores data for graphical display. CBL probeware sensors transform a graphing calculator into a mini-science laboratory system. CBL probeware systems allow students to conduct hands-on investigations with hardware and software that is generally easier to use, safer, and more precise than traditional laboratory equipment (Rogers, 1997; Krajcik & Layman, 1997; Bowman & Davis, 1997; Knapp & Glenn, 1996; Settlage, 1995; Linn, Layman, & Nachmias, 1987).

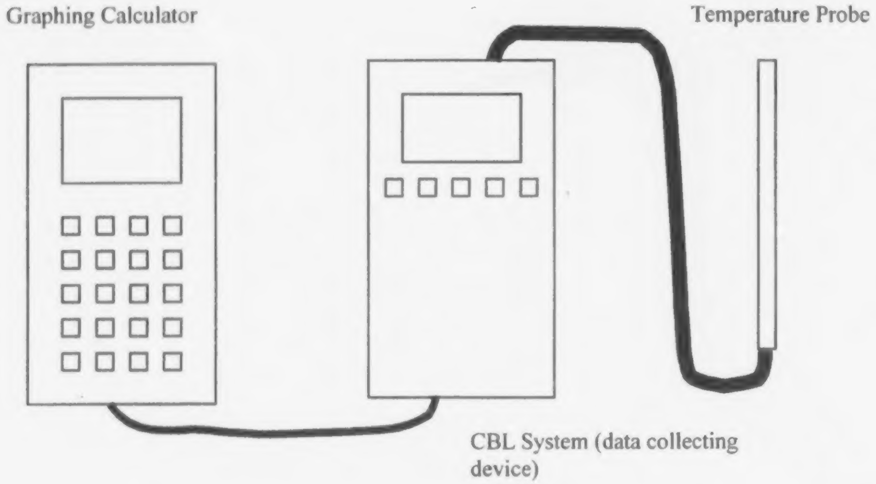

Figure 2. Calculator-based laboratory probeware system.

To integrate this technology adequately in their curriculum, teachers need to be technically proficient with the use of CBL probeware. Also, they need opportunities to discover what the technology can do for their students learning and teaching strategies for application in their curriculum. However, the process of adopting new technologies has never been quick or effortless in education. Like all professionals, teachers have their own cultural and contextual practices and accepted methods. These include instructional methods, teaching styles, and professional norms. Like other professional organizations, schools have organizational contextual characteristics that make change difficult. The unique culture of schools and changing societal expectations for them, create conditions that are substantially different from those of other work places (U.S. Congress, Office of Technology Assessment, 1995). Because of this unique culture, teachers' working environment is subject to the whim of societal influence. Teachers brought up in the environment of lecture followed by paper-and pencil drill or cookbook laboratory exercises, find it difficult to shift paradigms to the integration of CBL probeware technology in their curriculum (U.S. Congress, Office of Technology Assessment, 1995; Becker, 1991; Cuban, 1986).

Summary

As with all instructional technological tools, CBL probeware systems can be bewildering to use when first introduced to pre-service teachers. As these students were provided with opportunities to learn how to use this technology and implement it within the framework of their studies, they found it less challenging. The students' grew both professionally and in their confidence to use the technology. This resulted from their classroom experiences, collaboration with inservice teachers, and development of practical applications in their curricula. As they learned to operate and integrate CBL probeware, they overcame contextual and cultural influences that presented barriers to the facilitation of their understanding of CBL probeware technology within their curriculum. The findings of this study correlate with research concerning the implementation and integration of CBL probeware technology, Microcomputer-Based Laboratory probeware, and instructional technology with inservice teachers (Rogers, 1997;

Krajcik & Layman, 1997; Linn, Layman, & Nachmias, 1987; Dwyer, Ringstaff, & Sandholtz, 1991; Rogers, 1997; Settlage, 1995). Follow-up study of these participants will occur as they complete their student teaching/internship experiences and move into their first year of teaching.

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Appendix A

Pre-service Secondary School Science Teachers' Concerns
Regarding Calculator-Based Laboratory Probeware

Name ____
(Please Print)

The purpose of this questionnaire is to determine what concerns you have about using Calculator-Based Laboratory (CBL) Probeware. The items were developed based on typical responses of teachers who ranged from no knowledge regarding CBL Probeware to those with many years of experience. Therefore, some items on this questionnaire may not be applicable to you at this time. You should circle the numbers that correspond to your current view, considering how you feel about your involvement or potential involvement with CBL Probeware. Please respond to these items in terms of your own perceptions of what CBL Probeware involves. Please choose only one alternative, written comments in the margin are acceptable if you wish to comment.

Use the following scale to rate each item as it best represents your current view:

0	1	2	3	4	5
Not Applicable	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

1. I have very limited knowledge about CBL Probeware.	0	1	2	3	4	5
2. At this time, I am not interested in learning about CBL Probeware.	0	1	2	3	4	5
3. I do not know what CBL Probeware is.	0	1	2	3	4	5
4. I feel confident about using CBL Probeware within my science curriculum.	0	1	2	3	4	5
5. I wish to develop proficiency in using CBL Probeware in science.	0	1	2	3	4	5
6. I would like to know what resources are available for integrating CBL Probeware in my curriculum.	0	1	2	3	4	5

7. I would like to know what training is available to learn more about the use CBL Probeware. 0 1 2 3 4 5

8. I am concerned about the time I must invest in learning how to use CBL Probeware. 0 1 2 3 4 5

9. I feel that the training I received during my pre-service preparation helped my integration of CBL Probeware within my science curriculum. 0 1 2 3 4 5

10. I would like to know what effect of learning how to use CBL Probeware will have on my student teaching experience. 0 1 2 3 4 5

11. I am concerned about my technical knowledge of using CBL Probeware when working with students. 0 1 2 3 4 5

12. I am concerned about how the use of CBL Probeware affects students' attitudes about learning science. 0 1 2 3 4 5

13. I am concerned about my inability to effectively manage CBL Probeware when working with students. 0 1 2 3 4 5

14. I see CBL Probeware as a way to further motivate and excite my students to develop a better understanding of science. 0 1 2 3 4 5

15. I would like to know what current teachers are doing to learn how to use and integrate CBL Probeware within their science curriculum. 0 1 2 3 4 5

16. I would like to know my role as a teacher when I am using CBL Probeware with students during laboratory investigations. 0 1 2 3 4 5

17. I would like to know my students' role when using CBL Probeware during laboratory investigations. 0 1 2 3 4 5

18. I would like to know how CBL Probeware develops a better understanding of science instead of using traditional data collection instruments, such as a thermometer. 0 1 2 3 4 5

19. I would like to discuss the effectiveness of CBL Probeware in teaching science with current teachers to develop a better understanding of how to use this technology.	0	1	2	3	4	5
20. I feel that I could familiarize other pre-service teachers with how to use CBL Probeware.	0	1	2	3	4	5
21. Learning how to use CBL Probeware is a low priority for me because I am too preoccupied learning about other teaching strategies to be concerned with CBL Probeware.	0	1	2	3	4	5
22. Although I am not familiar with CBL Probeware, I would like to learn how to use it and integrate within my science curriculum.	0	1	2	3	4	5
23. I would like to share effective strategies with other pre-service teachers to further develop my understanding of how to integrate CBL Probeware within my science curriculum.	0	1	2	3	4	5
24. I would like to learn how to supplement or enhance my CBL Probeware hardware and software capabilities.	0	1	2	3	4	5

Complete the following two questions using your own words and ideas:

1. How would you use CBL Probeware in your science classroom?

2. What will support or hinder your use of CBL Probeware in your classroom?

PRESERVICE SCIENCE TEACHERS AND INTERNET TELECOMMUNICATIONS TOOLS: ISSUES TO CONSIDER

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The American educational system is currently undergoing a major reform initiative as a result of new telecommunications technology. A massive connectivity movement is occurring throughout American schools in response to a new national mission for students to enter the work force technologically literate in the 21st Century. Preparing students to meet the increasing demand for "knowledge workers" versed in telecommunications is the most commonly given reason for bringing telecommunications in the classroom (Shrum & Berenfeld, 1997). Advanced telecommunication skills are important in many occupations in today's workplace and these skills will become more essential in the near future. Preparing teachers to use instructional technologies effectively in the classroom is essential for student learning in today's society. Researchers conclude (U.S. Congress, 1995) that teachers are being inadequately prepared to use instructional technology and consequently are unable to effectively integrate technology into classroom teaching practices. Given the critical role of technology in the social and economical future of the nation, preparing teachers to effectively use instructional technology is critical (Northrup & Little, 1996).

Telecommunication Networks

In recent years, Internet connectivity in schools has advanced substantially as a result of increased attention from national policy making leaders and community leaders. The President's Educational Technology Initiative (Gore, 1996) calls for classrooms to be connected to one another and to the outside world and for teachers to be ready to use and teach using technology. In just three years, the percentage of U.S. public schools with Internet access increased from 35 percent in fall 1994 to 78 percent in fall 1997 (Bare & Meek, 1998). More instructional classrooms are becoming connected to online telecommunications. Bare and Meek also reported that the percentage of schools with Internet access in five or more instructional rooms per school increased from 25 percent in 1996 to 43 percent in 1997. A 1997 report from the National Center of Education Statistics (Heavside, Riggins, & Farris, 1997) indicated that 87 percent of the schools that lacked Internet capabilities reported planning to obtain Internet access by the year 2000. If these schools are able to acquire access, 95 percent of all American schools will have Internet access in the year 2000.

In recent years there has been a significant increase in the number of educators who use telecommunications networks, as well as growth in the number and quality of networked educational resources (Anderson & Harris, 1997). There are many common rationales for using advanced telecommunications to meet pedagogical goals. Frequently cited in current research are: Bringing real-world relevance into the classroom; helping students perceive knowledge as constructed rather than delivered from a book or teacher; providing students with an effective model for lifelong learning; strengthening social, communication, and critical thinking skills; meeting standards for inquiry-based learning; increasing the authenticity of the learning environment; changing the definition of the learning community to extend beyond classroom walls; finding role models for students; and promoting equity by providing all schools access to the same resources (Schrum & Berenfeld, 1997; SRI International, 1997).

Network use can help educators stay current with best practices in their field and help them to overcome problems such as teacher isolation. As with any profession, teachers need opportunities to expand their knowledge, keep pace with developments in their field, try out new innovative teaching methods, exchange ideas with peers and experts, and refine their skills.

Network exchanges present a prime opportunity for collaboration among teachers (Merseth, 1991). Teachers with access to telecommunications networks can contact other educators to discuss issues relating to their teaching practice, developments in their field, and classroom experiences.

Instructional Uses of Telecommunications in Preservice Education

Journals

Journals are currently being used in many preservice teacher education programs as a way to facilitate the development of reflective thinking. Few studies exist in the literature describing the use of electronic journals with teacher education students.

Russett (1994; 1995) describes the Secondary Science Education program at the University of Nebraska-Lincoln. This program loaned IBM computers with modems to each secondary science methods student and student teacher. The students submitted journal entries (minimum of one per week) by e-mail. The instructor replied within 24 hours via e-mail. Journal entries included thoughts, comments, and reflections concerning readings, class discussion, and practicum experiences. Russett (1995) found time and access to computers to be important considerations for student use of telecommunications. Students experienced problems with software and hardware. Russett contends that the technical problems students encountered influenced their attitudes.

Hutchinson and Gardner (1997) describe a program at the University of Central Florida in which a group of student teachers were asked to use the university-wide Pegasus e-mail system to keep in contact with the college coordinators who supervised their internships. Student teachers had free access to their university e-mail through the Florida Information Resource Network (FIRN), a free dial-up access Internet resource for Florida teachers. Students used e-mail to send daily reports, daily schedules, first impression papers and reflection journals/continuous logs to their college coordinator. Hutchinson and Gardner found that the use of e-mail has been most successful with the reflection journals/continuous logs. Students and college coordinators attested to the ease of e-mail use over the traditional forms of telephone and regular mail for communication.

Mentoring

There are some studies that can be found in the literature on instructional programs using telecommunications for mentoring preservice teachers in teacher preparation programs. These studies involved using e-mail with one-to-one communication between a university supervisor and a preservice teacher (Casey, 1994; 1997; 1998; Thompson and Hamilton, 1991), e-mail with one-to-one communication between a preservice teacher and an inservice teacher (Johnson, 1997), e-mail listservs with one-to-many communication between a group of preservice teachers and university supervisors (Loiselle, Dupuy-Walker, Gingras, and Gagnon, 1996; White, 1996; Zimmerman and Greene, 1998), and bulletin board systems with one-to-many communication between a group of preservice teachers and university supervisors (Thompson and Hamilton, 1991).

Casey (1994; 1997; 1998) reported the following benefits of telecommunications use during student teaching:

1. Increased reflectivity. Use of e-mail writing helped foster probing to promote deep understanding of teaching, to engage in a written conversation about experiences associated with their making meaning of teaching.
2. Increased feeling of rapport and support from university supervisor, access to other supervisors and university personnel.
3. Increased team support, decreased feeling of isolation.

4. Increased self-esteem due to mastering technology and receiving positive support through e-mail messages, increased pride from the professional documents they could create at home.

5. Increased knowledge and use of information access and retrieval as well as various types of technology such as multimedia.

Thompson and Hamilton's (1991) evaluation of the Electronic Education Exchange (EEE) project at Iowa State University revealed that merely making a telecommunications system available to the student teachers was not enough to get students to use the system. After students signed on to the network, they were each assigned a partner. The partner was another student teacher who was teaching at about the same grade level. Students were also assigned a faculty partner at this time. Special conferences were also initiated on this system whose purpose was to provide a place on the system where student teachers could talk about particular ideas in the areas of classroom management and parent interactions. Pre- and post- survey data revealed that student teacher attitudes toward technology were significantly more positive after their network experience. Thompson and Hamilton (1991) concluded that further structured intervention may be necessary to encourage student teachers to communicate with faculty and experienced teachers in a telecommunications network.

Loiselle et al., (1996) describe an exploratory experiment which took place in two Canadian universities, Universite du Quebec a Trois-Riveres (UQTR) and Universite du Quebec a Montreal (UQAM) in which preservice teachers used e-mail listservs to discuss critical incidents occurring during their student teaching practicum. Students had to describe and analyze at least two experiences weekly and were required to react twice a week to other messages. Preservice teachers appreciated the fact that they had, without delay, useful advise and feedback related to the situations they encountered. They also considered the diversity of points of view given by peers or supervisors as a positive aspect . University supervisors viewed the experiment as an opportunity to develop new supervision methods as well as experiencing different ways of helping student teachers at the moment they are experiencing difficulties.

Loiselle et al., (1996) contended that the CMC medium of electronic mail provided an effective means for developing collaboration between colleagues, peers, and mentors. Participants used e-mail as a way to express concerns and satisfactions with their accomplishments. Participants also used e-mail to ask for help and exchange "tricks of the trade" from peers or expert teachers. The help of the university supervisor transformed the use of electronic mail to develop and sustain reflective thinking. Supervisors can become models by showing ways to go deeper than superficial descriptions of daily events. They often enrich their reactions with pedagogical theories and practical knowledge. Using the electronic network, supervisors have the opportunity to question the students' assertions, open different aspects of a problem or apply reflective thinking on the case presented. Because e-mail permits immediate feedback, it contributes very effectively to the shaping of reflective thinking. These findings were also substantiated by Zimmerman and Greene (1998), who found that the use of listservs guided by faculty provided opportunities for student teachers to engage in reflections and dialogue, providing ongoing opportunities for pedagogical concepts to be discussed and examined.

Johnson (1997) describes a project designed to provide an avenue for preservice teachers to gain a greater understanding of different philosophies of reading through collaboration with practicing teachers across the country via electronic dialogue. Each preservice teacher in a reading methods course was provided an e-mail account through the university and was assigned mentor “e-pals” who were practicing elementary teachers located in various regions of the USA. There was no requirement as to how many times a student had to communicate with the mentor e-pal. As a result, communications ranged from weekly to once or twice for the entire semester. By incorporating electronic dialogue into the reading methods course, students were able to see telecommunications as a multi-faceted resource and used telecommunications technology as a tool for communicating, problem solving, brainstorming, and information gathering. This project provided students with a broader set of experiences during their field placement by extending the face-to-face collaboration through electronic dialogue. The mentors were able to share their experiences as classroom teachers as well as encourage students to view technology as a tool to improve their professional lives. In a similar study, Taylor (1998) contended that students were motivated by active learning that had an authentic purpose.

E-mail and E-mail Listservs

An emerging area of research in telecommunications use in educational settings deals with the use of e-mail listservs in instruction. These studies have examined the types of interactions possible among correspondents on an e-mail listserv, the validity of using the medium for meaningful instructional interactions, factors that enable university-based instructors and novice teachers to integrate electronic mail into teacher education, and attitudes of preservice teachers toward technology.

Sunal and Sunal (1992) investigated the adaptation and use of LAN (local area network) technology as an educational enhancement and as a social process in a university teacher education program. The subjects were grouped into one control group (no LAN access) and two experimental groups (restrictive LAN access and facilitated LAN access) determined by placement in schools with varying facilitative and administrative support for incorporating LAN technology. In sites where LAN use was facilitated, novice teachers averaged more than five contacts each week using LAN communication types (e-mail and facsimile machines). Most communications between participants involved seeking help and approval in lesson planning, selection of alternative classroom activities, and decisions about classroom management. Other less frequently encountered communications dealt with identifying sources of materials, discussing ideas for lessons, clarifying assignments, and reporting novice teacher progress. The experimental facilitated group had a higher frequency of message content related to alternative classroom activities and classroom management than did the experimental restricted group. Sunal and Sunal (1992) concluded that ease of contact, favorable attitudes toward use of technology in schools, types of message content, and frequency of the communications increased for participants in settings with facilitative administrative support. Furthermore, these effects were related to novice teacher science lesson-plan performance in classrooms.

Zimmerman and Greene (1998) summarized five years of telecommunications use with preservice teachers during their student teacher internship at the Reich College of Education at Appalachian State University. During the 1993-94 school year, 16 students and 5 faculty communicated with one another using an e-mail listserv for a year one project. A listserv was designated for the discussion of concepts, issues, and reflections related to communication skills, social studies, math, and classroom management during the student teacher internship. Listserv entries were analyzed for discussion of critical concepts taught in the methods courses. Connections between concepts and application in the classroom were noted during this study. Unstructured listservs were used by student teachers mostly for social and emotional support. The use of listservs guided by faculty provided opportunities for student teachers to engage in reflections and dialogue, providing ongoing opportunities for pedagogical concepts to be discussed and examined.

Piburn and Middleton (1998) examined interaction patterns between preservice mathematics and science teachers and university faculty on an e-mail listserv. They reported that conversations that promoted the most reflection for the longest periods of time were centered around content and pedagogy. Procedural queries and technical questions on the listserv were short to the point, and limited to a specific event or activity. Piburn and Middleton contend that an unstructured listserv exists as a true conversation in which students are able to question, reflect, plan, and respond to topics of mutual interest.

Electronic Communities of Networked Educators

The establishment of an electronic community network of preservice teachers is perhaps the most meaningful prospect that online telecommunications has to offer to preservice teacher education programs. An electronic community network of preservice teachers is a virtual community of student teachers who share teaching experiences, problems, new ideas, and pedagogical resources. These networks offer preservice science teachers a vehicle to engage in reflective discourse with university supervisors and faculty from their remote student teaching locations. Some studies have been conducted using e-mail listservs and bulletin board systems with a cohort group of preservice teachers during their student teaching internships (Bull et al., 1989; Merseth, 1991; Schlagal et al.,1996; Thomas et al., 1996; Waugh, 1996). Of these studies, three have analyzed e-mail postings for the type of discourse generated on listservs used in preservice teacher education instructional courses (Schlagal et al., 1996; Thomas et al., 1996; Waugh, 1996).

Electronic community networks of preservice teachers can provide socioemotional support to a cohort group (Bull et al., 1989; Casey, 1997; Merseth, 1991; Schlagal et al., 1996; Thomas et al., 1996). Preservice teachers use networks to share and discuss common experiences. Interactions often include sharing student teaching experiences and discussion of student teaching issues (Thompson & Hamilton, 1991). Electronic communities offer an environment to interact personally, socially, and professionally by sharing thoughts, seeking advice, and sharing experiences with successes and problems over geographical distances (Caggiano et al., 1995; Harasim et al., 1995). This sharing of experiences appears to reduce isolation barriers that preservice science teachers often encounter during their student teaching experiences. In addition, using computer networks facilitates communication between preservice teachers and university supervisors and instructors (Waugh & Rath, 1995). Finally, telecommunications technology provides a medium that enables students to collaborate with one another as part of the learning process and facilitates information exchange (Harasim et al., 1995).

Barriers and obstacles exists to the successful implementation of electronic networks with preservice teacher instruction. Student teachers have reported problems accessing networks due to lack of phone lines and access to modems in their school placement (Thompson. & Hamilton, 1991; White, 1997). Students often experience a tremendous amount of anxiety and frustration using e-mail (Campbell & Zhao, 1996). Purpose, ease of access, and convenience for task completion are important factors in promoting e-mail use, but users may perceive writing rather than speaking a type of depersonalized learning (Thomas et al., 1996). Often, students find e-mail helpful in communicating with instructors outside of class, but many perceive this to be time consuming, and of little worth. Students perceive not owning a personal computer as a barrier to using an electronic network (Zimmerman & Greene, 1998). Furthermore, students perceive using computer networks as being inconvenient (Waugh & Rath, 1995). Students may send messages to wrong conference topic areas that create confusion for participants (Harasim et al., 1995).

Preservice Science Teachers Using an Asynchronous Web-Based Forum

In order to examine the potential benefits of preservice science teachers engaging in an electronic professional community of science teachers on the World Wide Web, a public Web-based forum called the SciTeach Forum was constructed in July 1997. The SciTeach Forum was placed in the context of a large public science education Web site. The SciTeach Forum serves as an online support network for both inservice and preservice science educators.

The SciTeach Forum was designed to be a place where science teachers share ideas, reflections, and conversations on teaching and implementation of technology in the classroom and other instructional pedagogy, while also providing support for each other as members of an electronic professional community. The SciTeach Forum was designed with NetForum software. A simple, intuitive toolbar allows user access to NetForum features. Forums can be created and managed by "forum owners" with the administrative tools via the World Wide Web. Forum topics and messages can also be edited via the administrative tools. Forum owners can customize many of a forum's features and can add html codes into the headers and footers of each of the forum's web pages.

The NetForum software was selected to create the SciTeach Forum because it was available at no monetary cost since our institution has a site license to use the software. Another reason to use the NetForum software for this project is ease of use. In addition, the software allows the users to initially structure the discussion topics on the forum in any order. The software also enables any user to add a new discussion topic to the forum. Within each topic area, a user can post a new message, reply to a message, or reply to a reply of a message. When users first enter a topic area, they are presented with a list of message and reply titles. Each message and reply title displays the author of the message and the date the message was posted on to the forum. Message threads are displayed in a temporal sequence with the most recent message listed at the top of the screen. Each message and reply title is a hypertext link. The user clicks on a message or reply title to view the posted message. The software also enables the user to read an entire thread of successive replies to the original message.

The SciTeach Forum can be accessed by anyone with a connection to the World Wide Web. A special e-mail account or password is not a requirement to read forum messages or post messages to the forum.

The SciTeach Forum contains discussion topics relating to teaching science content, incorporating instructional technology into the curriculum, and topics relating to teaching pedagogy in general.

Data Collection

A survey was administered to each subject at the end of their student teaching semester in the Fall of 1998. The survey consisted of open-ended questions, Likert-type attitudinal questions, and multiple choice type questions designed to identify the preservice science teachers' perceptions and attitudes regarding their experience interacting with a Web-based forum during their student teaching internship.

Nine interviews were conducted from a stratified random sample of preservice science teachers. Preservice teachers were stratified based on their methods course. Three subjects were interviewed from each of the 3 different methods courses. The interviews addressed the participant's experience, attitude, and perceptions with using the Web-based forum during the 5 weeks of on-campus course work and during their student teaching internship. Three interviews were conducted during the second week of the participants' student teaching internship and six interviews were conducted during the week following the end of the participants' student teaching internships. Interviews were recorded using audio tape.

Comfort Level with Web-Based Communication

> "I guess it's more informal, Web-based. When you are face-to-face with someone, you would be on your best behavior. You don't have to worry about your manners when you are sitting there typing. I don't feel like that's a formal way of communication. It's zapping information to somebody and zapping it back and there's no person-to-person contact."

This participant perceived Web-based communication as not being a formal way of communicating. The rules for communication are different in a Web-based medium. Many participants reported they can ask questions and make comments in the Web-based forum that they felt uncomfortable doing in a face-to-face setting. The Web-based medium enabled participants to feel less inhibited to "say what they truly feel" and discuss how they genuinely think regarding a topic or issue. The participants did not experience feelings of nervous tension communicating on the forum. Furthermore, some participants felt it was easier to give a more honest opinion when they were not directly speaking face-to-face with an individual.

The absence of a physical presence and low social context cues on the Web-based forum enabled participants to feel comfortable communicating in the medium. As one participant stated:

> "I would say I'm an extrovert and I enjoy face-to-face communication. But there are more times when I would feel more comfortable with the Web, perhaps speaking with a professor that I felt a little uncomfortable with. It's a lot easier to communicate using Web-based communication because there are a lot of cases where you feel uncomfortable asking questions in front of a class or asking questions to a teacher because you feel like they might think of you as being stupid."

This participant stated that she felt uncomfortable talking in front of a class due to fear of being perceived as less-knowledgeable than other students. Harasim (1990) contended that text-based interactions diminish stereotyping associated with external social status. In this respect, the Web-based medium facilitates discourse by removing visual cues that promote assumptions pertaining to established social hierarchies and dominant personalities.

Not all participants felt comfortable engaging with the Web-based forum. One participant stated:

> "I'm more comfortable with the face-to-face [communication] than I am with the Web-based [communication]. I'm not really proficient on computers. And posting those things on the forum, I was always paranoid they weren't going to go through. I just don't rely on that kind of thing. I would never put everything solely on a computer. Like my life on a computer for fear of a crash or something."

This participant was more comfortable with face-to-face interactions because of her previous computer technology experience. Although this participant had positive experiences participating in the forum discourse, she continued to have anxiety about using computers for telecommunication purposes. Even with successful forum involvement, a fear of the unknown with implementing computer telecommunications technology can endure.

Feedback

Receiving feedback in delayed-time was perceived as being a non-advantageous aspect to communicating on the forum. Because the majority of participants accessed the forum only once a week (n=22), feedback to immediate classroom concerns (discipline problems and other management issues) "came too late to be of any use". Many participants perceived having immediate feedback to difficult situations they encountered during their student-teaching internships as imperative. As one participant stated, "With knowledge and information, the sooner you have it, the more easier it is for you to use it." Infrequent access to the forum did not facilitate an immediate response to participants' urgent concerns and situations. In some cases, participants did not receive any feedback to their postings.

The participants perceived dialogue on a public Web-forum of science educators as being advantageous to their particular situation. A variety of people who the participants could otherwise not have been able to communicate with provided feedback. Feedback from disparate people allowed the participants to see different aspects of an issue or problem. Our participants were exposed to ideas and notions of science educators who would not have been a part of a restrictive network. If the network was restricted "you would have a limited supply of resources and it would make it difficult to have a large variety of responses." By restricting a network, the knowledge base becomes more limited thereby reducing the amount of feedback one receives. Network participation from science educators who were not involved with the participants' methods course instruction provided additional insight and perspectives to issues that our participants were dealing with in their classrooms.

Reflective Thinking

The asynchronous nature of the forum provided the participants with the opportunity to think and reflect on their teaching. A main difference asynchronous, Web-based communication has over face-to-face communication is that "you can say what you need to say and/or change it before you actually send it." Many participants stated that their forum communications were "well thought out". Since the forum discourse is preserved as a permanent record, the participants are conscientious about what they post to the forum. Similar to previous studies (Berge, 1997; Harasim, 1990), our participants felt that the asynchronous medium allowed them more time to think and reflect before responding to postings. Reading and responding to forum postings forced the participants to reflect, form ideas, and reexamine their own understandings and interpretations. However, this may not be the case for all individuals:

> "In Web-based you may not think about it, but then you could. Several times I've half-way typed something and be like that sounds stupid. So I'd erase it and start over again. So, maybe

its more well-thought out when its Web-based. Or not. It could go one way or the other. You could just do it and not really think about it."

An impetuous individual might react to a posting on impulse without really thinking or reflecting. A few participants stated they were sometimes quick to post responses to the forum without careful reflection. Several participants asserted that a lack of personal time, due to the amount of work that was required of them during their student teaching internship, was the reason for this.

Impersonal Nature

"In face-to-face communication, you can see someone's emotion and how they express themselves. A lot of times, you can tell something about a person by their posture, whether they have a closed type of posture or an open posture, if they're happy about the way things are going or they're not so happy. You know that a person understands what you want to say. In Web-based, it's all what they write or what they type on the screen."

The participants perceived the Web-based forum as being more impersonal than face-to-face interactions. Participants could not see the emotion behind one's responses. Since there was lack of visual cues on the forum, it was sometimes difficult for participants to comprehend the exact meaning of what a person was trying to communicate. Face-to-face communication involves physical cues and interactions including hand gestures, facial expressions, voice intonations and body posture. These physical cues help to provide meaning and aid in understanding the context of a spoken discourse. The absence of social context cues in Web-based discourse changes one's conventional rules of communication. One can not rely on physical cues to facilitate understanding in the Web-based medium. This can be advantageous because it focuses the communication exchange more on the content of the message and not on the characteristics of the speaker.

Promoting Discussion

An assortment of factors appeared to promote discourse among the participants. The level of interest in a topic appears to be an essential factor in promoting discussion. The immediate relevancy of a topic to a participant at a particular time is also an influential element to the depth of the dialogue. Furthermore, interpersonal factors among participants were salient elements in promoting discourse. The participants were a group of preservice teachers experiencing similar situations during their student teaching internships. As the participants encountered similar classroom management and discipline problems, they used the forum to share and discuss their related situations.

Discussion of controversial topics also increased the depth of the forum dialogue. As one participant stated,

> "When you get fired up about something and you're really interested and passionate in an idea, I think you are going to talk about it more than if you just feel so-so about it. If you're not real sure how you feel then you are not going to respond as much. But if you know what you're thinking, then you're going to talk a lot more. You're going to have a lot more to say."

On the forum, participants expressed their personal opinions and views in discussions involving ethical issues. Throughout the discourse and in the participants' interviews, several critical incidents were referred to as "touchy" or controversial issues. Discussing controversial issues was perceived by these participants as getting them "fired up". Furthermore, they were interested in hearing what their peers thought or how they would react to a given situation. In the discourse, participants explained and defended their moral positions and beliefs. Some participants also said they were more willing to contribute to the discussion of sensitive issues than to other topics.

The forum promoted discussion by allowing one access to others' perspectives. It allowed for different opinions to be analyzed and agreed with or argued against. For students who were isolated in their student teaching placements, the forum promoted discussion just by being there. The forum provided a place where isolated student teachers could share and discuss their teaching experiences.

Inhibiting Discussion

The interface of the Web-based forum appeared to be a factor that limited the depth of discussion on the forum. Replies to posted messages are organized temporally with the newest reply at the bottom of the message thread. This mirrors the organization of a bulletin board system. Users could also read an entire thread of successive replies to an initial message. In this manner, an entire thread resembled a face-to-face conversation. However, the nature of communicating asynchronously in a temporal, linear manner was sometimes perceived as restricting the discourse.

> "It's not an immediate dialogue. Its put a question up there or a problem up there and somebody replies back and you read it whenever you get to a computer. It's not a constant dialogue. It's not back and forth, back and forth, back and forth. It's a posting, then a reply. That's it. Because it's not immediate, you can't really challenge it or ask more questions or ask to go into further detail. Not the way it was set up. I guess you could e-mail that person and ask them. But as far as the forum went, it wasn't set up that way."

The nature of asynchronous communication does not promote an immediate back-and-forth dialogue that is often required by a person to get the specific type of feedback one is looking for. When one engages in face-to-face conversation, the nature of the communication is often a continuous process. The forum interface does promote a reply, but not a "back and forth, back and forth" discussion. A natural flow of conversation is not easily achieved when participants access the forum on a weekly basis. Participants viewed the forum's linear structure as impeding the flexibility of the communication because they could not place their replies directly to specific messages in a thread.

A large number of participants responding to the same critical incident appeared to cause a saturation effect in the discourse. In many of the message threads, after half of the students responded, the responses began to "sound along the same lines". One participant shared her insight to this phenomena:

> "I think people will wait to see other people respond to it. And then pull their responses up on the screen and be like okay, this look good. I'll type that down as well. Versus sitting down and really thinking about the incident and being like, well, this is the way that I would handle it, let me see someone else's view, but this is the way I'm going to handle it. Versus comparing and contrasting, they'll just take the easy route out and write just what someone else has or type out what someone else has."

Some participants read the postings of others and then contributed to the dialogue by restating previous ideas by adding "a new twist" to the discourse. In some cases, the participants responded to a critical incident without reading the responses of others. However, this was not the case for all participant postings in the latter stages of the thread. There were students who often posted toward the end of a message thread with a reflective posting that built on the ideas of others. In order to reduce this saturation effect, one might want to consider reducing the number of participants responding to a critical incident, or have a group of students adopt different thinking-related roles in their response to the discourse generated in a critical incident thread. These roles could include a "devil's advocate", speculator, brainstormer, optimist, pessimist, or judge. Even though we structured critical incidents with dialogue prompts to intentionally promote discussion of science-specific pedagogy, it appears that more structure is required in order to facilitate large group discussions on the Web.

Conclusions

The findings in this study illustrate a variety of factors that influenced the discourse of preservice science teachers using an asynchronous, non-restrictive public Web-based forum. The asynchronous nature of the Web-based forum allows preservice teachers to communicate in a reflective online community at their convenience. Many of the message threads that occurred on the forum were topics that were not part of the preservice teachers' in-class instruction. The forum offered new opportunities for participants to discuss and reflect on classroom issues that were directly relevant to their student teaching experiences. The findings also revealed there are some constraints and limitations with using asynchronous communication with preservice teachers. These include receiving feedback too late to be of use and issues pertaining to the absence of visual cues during discourse exchanges. Moreover, if we expect preservice teachers to use telecommunications tools to engage in reflective communities of practice, then it is important that time be provided in their daily routine to use these tools to reflect on their practice.

The conventional rules of communication change in the online medium. Non-facial communication issues are intrinsic to this situation. Communication exchange is not guaranteed among all participants since participants can chose selectively which postings to read or not to read. Most participants (n=28) stated that they read messages posted on the forum by scanning the content for issues of interest, while disregarding messages or skimming others. One participant stated that he usually skimmed through messages and read only those posted by peers from his methods class. Furthermore, the comfort level with the Web-based medium itself might be a factor to how students communicate with each other. In Web-based communication, there are no personal nuances such as facial expressions or hand gestures which accompany the dialogue. Since the forum provides a means to communicate asynchronously, it permits the more timid and reflective learners in a group a chance to participate in the discussion more than they might in a face-to-face conversation. The structure of the forum also enables each participant the opportunity to have time to reflect on what has been said, think critically, and then respond.

With more than sixty different asynchronous conferencing software packages available to use (see Woolley, 1998), more research needs to be conducted to determine the most appropriate design structure to use with a public, non-restrictive asynchronous Web-based forum. Ease of use with respect to the design structure is an important factor to consider. Most asynchronous conferencing software packages use either a linear or hierarchical tree structure. Linear structures add a reply in a temporal manner to the end of a linear chain of messages. A hierarchical tree structures allows a user to attach a response directly to any message. This allows a discussion to potentially branch out infinitely. The linear structure is simpler to navigate and more closely resembles a face-to-face conversation. However, some of our participants felt frustrated with the lack of flexibility in the linear structure and wished the forum provided a hierarchical tree structure. Although we view the linear structure as easier to navigate, some participants still experienced difficulty locating older messages threads on the SciTeach Forum.

Conferencing in delayed-time versus real-time with preservice teachers placed in remote geographical internships remains an issue to be further explored. A disadvantage some participants perceived with using asynchronous communication was that they did not receive immediate feedback to problems they were experiencing in their classrooms. Using synchronous communication with preservice teachers could provide for immediate feedback to problems and concerns they experience in their classrooms. Furthermore, a synchronous environment would enable participants to participate in a dialogue which more resembles a face-to-face interaction. We believe that the logistics of coordinating synchronous communication with our participants would have been extremely difficult given the resources in their school placements and their schedules. Unless provisions could be made to ensure each participant has access to a networked computer and busy schedules could be coordinated, engaging preservice teachers in synchronous communication would not be feasible.

We have just embarked on a journey to understand how preservice teachers use asynchronous communications in a public, non-restrictive Web-based forum. We are learning how the structure of a Web-based medium promotes learning in a social context. As higher education continues to integrate Web-based tools into teaching pedagogy, it is important that we continue to analyze and research the mechanisms that facilitate learning online.

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THE 10th ANNIVERSARY OF A SUCCESSFUL ELEMENTARY SCIENCE TEACHER PREPARATION PROGRAM

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Angela Steffen, University of Northern Iowa

Teachers, as products of an education system, acquire behaviors through experiencing school for seventeen or more years (Bryan & Abell, 1999). For decades this has included twelve to thirteen years of passive listening and regurgitation, followed by more years at the post-secondary level refining these skills (Fosnot, 1989). In his discussion of the culture of teaching David Ost provides a description of how we teach as we were taught without actually using this time worn phrase. "Thus potential teachers enter the profession with well developed sets of rules that will govern teacher behaviors." (OST, 1989, pp. 165). These sets of rules are the products of a passive learning system and result in teachers who continue to produce passive learners. Teachers carry with them existing conceptions of teaching and attitudes toward teaching (Bryan & Abell, 1999;Tilgner, 1990; Wink, 1999). These beliefs include their use of pedagogy similar to that which they experienced or to that which they preferred as a student (Mellado et al., 1998). Introducing new teacher behaviors incongruent with the conditioned views held by preservice teachers results in little attention to the advocated behavior. Science educators striving to follow the reform initiatives (AAAS, 1993; National Research Council, 1996;Rutherford & Ahlgren, 1990) and create empowered learners and empowered teachers (Fosnot, 1989) must create preservice programs modeling reform efforts in both content and methods over a period of time. Preservice teachers must undergo conceptual change about teaching as well as changes in methodology and attitudes toward teaching science (Mellado et al., 1998).

Though efforts to create conceptual change in preservice teachers must be rooted in teaching and learning at the K-12level, those efforts must simultaneously be accompanied by similar changes in post-secondary science methodology and attitude. Teachers who learn in a different way will teach in a different way and ultimately those of their students who become teachers will been cultured with a different model of teaching.

In 1984 Zeitler noted that little was written on how to improve or change the inadequate preparation of preservice elementary teachers. He recommended the integrated teaching of content and process. Ten years later Ernst (1994) researched the in adequacy of teachers' preparation and the characteristics they perceived as adequate preparation. She provided several recommendations, among them that teacher preparation programs should: a)develop a strong foundation of science content, b) provide opportunities to experience science as a hands-on, inquiry-based process, and c) provide opportunities to observe good models of science teaching. These recommendations speak to the reconceptualization of the entire preservice science preparation program.

Recent literature describes attempts at changing the nature of preservice science teaching methods courses (Anderson, 1997; Butts et al., 1997; Greenwood, 1996) and the accompanying field experiences (Bryan & Abell, 1999) to provide good models of science teaching and elicit changes in preservice teachers attitudes about science and teaching science (Pedersen & McCurdy, 1992;Stefanich & Kelsey, 1989). However, in situations where it is possible, more than the science methods courses must be changed.

One answer to the criticism about the lack of improving inadequate elementary science teacher preparation includes attention to the understanding of science by the teachers themselves. The effects of inadequate science content background have been well documented in (Boone & Gabel, 1998; Butts et al.,1997; Greenwood, 1996; Hammrich, 1997; Mulholland & Wallace, 1996).Content knowledge is also linked to comfort and confidence in teaching science (Jarrett, 1999) and thus to preservice teachers' attitudes toward science and their ability and desire to teach it (Lucas, 1982; McDevitt et al., 1993; Pedersen & McCurdy, 1992; Stefanich & Kelsey, 1989).

Since culturally derived beliefs about teaching are very stable, most initial modifications in teacher education have little effect on systemic change. For this reason, total program efforts stand the best chance for successfully altering how elementary teachers teach science, and ultimately how future elementary teachers are introduced to and learn science through their K-12education. The program presented here provides an example where changing the culture of learning changes the culture of teaching. Teaching teachers as you would have them teach is effective.

The Program

Program History

This presentation describes a program that we believe successfully teaches science and pedagogy at the post-secondary level in a manner which models the advocated approaches to teaching elementary school science. The program was initiated through a National Science Foundation Teacher Enhancement project(TPE-8851116) from 1988-1993 and a previously funded National Science Foundation CAUSE grant from 1977-1980. What this program does is teach preservice science teachers differently so they will teach their students differently.

The beginning of this program actually started in 1977 with a National Science Foundation CAUSE grant to develop two general education science courses for non-science majors. Activity Based Introductory Science I (ABIS I) and Activity Based Introductory Science II (ABIS II) constituted a two-course sequence fulfilling the general education requirement for science at the University of Northern Iowa. Each course was three credit hours with four contact hours, activity based utilizing a thematic approach, and included four interdisciplinary units. The courses were team taught by science education faculty from various departments within the College of Natural Sciences. The integration of laboratory with lecture and the interdisciplinary, thematic-process orientation was a novel idea in 1978 when these courses were first offered to about 60 students. By 1981 the courses were fully assimilated into the general education program with enrollments of 120students per course per year.

By 1986 course popularity had increased, the university general education program was being remodeled, and interdepartmental staffing had become administratively problematic. Thus, in

1987, ABIS I and II were reorganized through a university minigrant into Activity Based Physical Science (ABPS) and Activity Based Life Science (ABLS) and increased to four credit hours. They continued to have thematic designs and the integrated lecture/laboratory format but staffing was aligned within individual departments. The courses were restricted to elementary education majors with an increased emphasis on inquiry and modeling of pedagogy appropriate for teaching science through inquiry. Continued enrollment pressures on the courses subsequently resulted in the four sections per course per year being increased to six sections per course per year serving 180-190 elementary education majors in each course per year. These efforts in teaching science content to future elementary teachers paralleled part of the preservice preparation program instituted at Eastern Michigan University during this same time period (Phillips, 1984).

In the mid to late 1980s, the National Science Foundation (NSF) funded several elementary teacher preparation programs in mathematics and science as part of their teacher enhancement initiative. ABPS and ABLS became the cornerstone courses for the development of a K-6 Basic Science Minor as part of the funded Preparation of Elementary Mathematics and Science Teachers (PEMST)program at the University of Northern Iowa. Other programs in this initiative established course sequences in content and methods for both mathematics and science or only science: the QUEST program at Indiana University, Project STEP at Madonna University, COSTEP at the University of Northern Colorado, and other innovative model programs at Kansas State University, the University of Wyoming, and Mississippi State (Gardner & Cochran,1993).

Some of these programs include all of an institutions' elementary education majors: Indiana University(Boone & Gabel, 1998), University of Northern Colorado (McDevitt et al.,1993; McDevitt et al., 1999), the University of Wyoming (Stepans et al.,1995), and Kansas State University (Shroyer et al.,1996). Others are directed towards a subset of elementary education majors desiring an emphasis in science, such as one facet of the Indiana University program (Boone & Gabel, 1998) and the PEMST program at the University of Northern Iowa

(Ward, 1993). The literature also offers examples of reform-based changes in science content courses at Clemson (Fones at al., 1999), Pennsylvania State University (McLoughlin & Dana, 1999) and specific information on the biology course in the model program at Kansas State University (Stalheim-Smith & Scharmann, 1996).

Program Overview

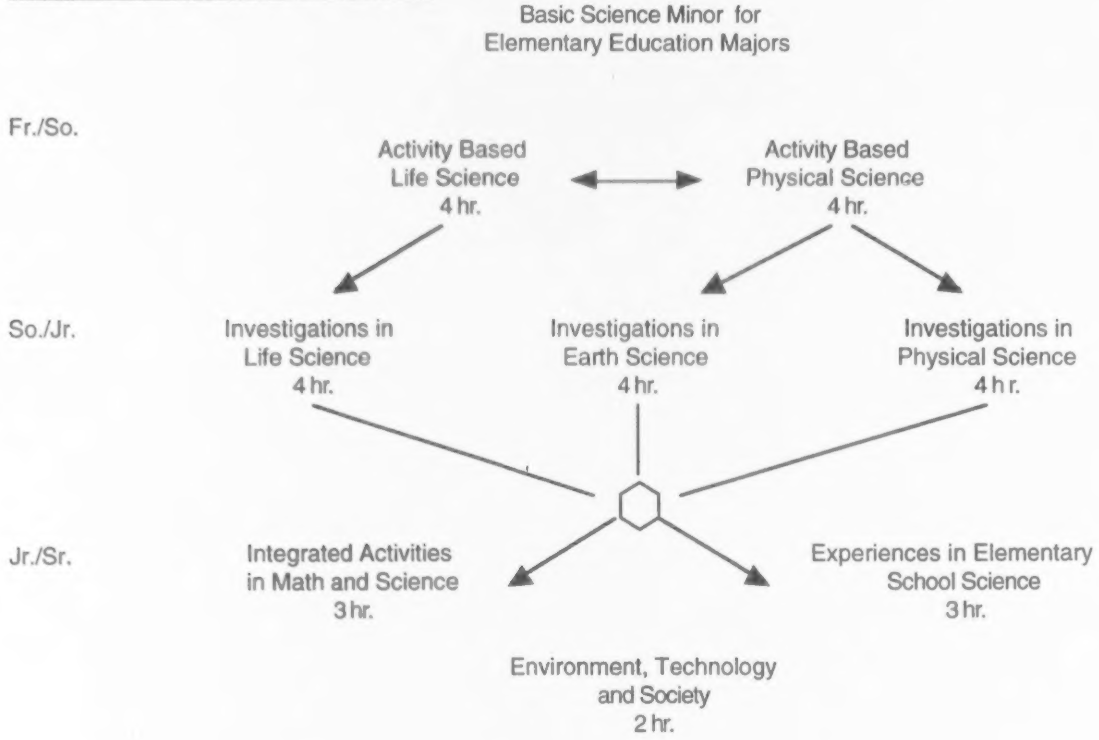
The PEMST program created parallel programs in mathematics and science for elementary education majors seeking state endorsement in K-6 mathematics or science (Ward, 1993). Though the Basic Science Minor was created prior to the publication of national science reform initiatives of the late 1980s and early1990s, it contains many of the emphases outlined for teaching, teacher preparation, and professional development. The Basic Science Minor also includes three of the characteristics identified by Ernst (1994) as providing adequate preparation for teaching science: strong science content knowledge, opportunities to experience science as a hands-on, inquiry-based process, and opportunities to observe good models of science teaching. Major PEMST goals were a) to prepare outstanding elementary math and science teachers with strong discipline backgrounds, and b) to build a support network for field experiences and student teaching which would extend into initial inservice years thus encouraging graduates to assume leadership roles in teaching mathematics and science in their schools. These intentions were manifested in four areas in program development. The first three areas constituted the mathematics and science minors for elementary education majors. Important aspects include :a) content courses that foster an understanding of concepts and processes while modeling problem solving, critical thinking, and appropriate pedagogy, b) methods courses oriented towards preservice teachers' experiences in integrating theory with practice via activity-based teaching, and c) pre-student teaching field experiences which encourage the application of content and pedagogy as taught in the Minor courses further supported by special student teaching placements to continue these emphases. The fourth area consisted of developing an induction year support network for program graduates to assist in the transition from preservice to inservice. This included the initiation in1990 of a cadre of teacher-mentors in various in-state locations.

Program Description

The Basic Science Minor consists of 25 credit hours which includes both science content and pedagogically oriented courses (Figure 1 and Appendix). The remainder of this presentation concentrates on the course sequence and course descriptions, the pedagogical foci of the content courses, and the relationships to other courses in the minor and to the elementary education major.

Figure 1

Overview of the Basic Science Minor


Basic Science Minor for
Elementary Education Majors
Fr./So.
Activity Based Life Science 4 hr.
Activity Based Physical Science 4 hr.
So./Jr.
Investigations in Life Science 4 hr.
Investigations in Earth Science 4 hr.
Investigations in Physical Science 4 hr.
Jr./Sr.
Integrated Activities in Math and Science 3 hr.
Experiences in Elementary School Science 3 hr.
Environment, Technology and Society 2 hr.

Two of the introductory content courses, the ABLS and ABPS courses described earlier, act as part of the university's general education program, while the third general education requirement, a capstone-type course, Environment, Technology and Society, serves as an additional content course. Both of the Activity Based courses are taught with an inquiry approach. ABPS has a process and model emphasis and includes units in: naked eye astronomy and earth-sun-moon relationships, rocks and minerals, and energy relationships in physics and chemistry. ABLS features a process and system emphasis in units on: diversity, life cycles, reproduction and development, and ecosystems. Currently both courses are taught in two double period classes per week, with the ability to move seamlessly between lecture/discussion and laboratory facilities as the flow of the class indicates. They feature activities which develop concepts indicated by elementary science standards, but taught conceptually at the post-secondary level.

The second tier of four credit hour, five contact hour content courses consists of Investigations in Earth Science, Investigations in Life Science, and Investigations in Physical Science. These courses build on the concepts, processes, and modeling of pedagogy in the Activity Based courses, with the explicit use of a learning cycle as an inquiry teaching approach. Since these three courses carry ABLS and ABPS prerequisites they are taken mostly by Basic Science Minors and their smaller class size (12-18) allows concept discussions rather than lecture.

An overview of one Investigations in Life Science lesson will explain the general framework of these Investigations courses. The Investigations in Life Science class meets two class periods on Monday and Friday and one class period on Wednesday, providing ample laboratory time on Monday and Friday for exploratory and application laboratories with Wednesday devoted to concept development discussion; or time to complete most/all of a learning cycle in one 110 minute class period on Monday or Friday. One Monday was recently devoted to brainstorming what students already knew about the heart and circulation, then taking blood pressure, listening to heart beats, exercising and repeating this, and then using physical and technologically-based models of the heart and the circulatory system - all of this to explore the human cardiopulmonary system. Wednesday was a BIG discussion relating heart sounds and pulse rates to what was happening in the heart and bloods vessels, finding out what those blood pressure numbers actually mean, etc. Friday's time was given to applying this knowledge via student-generated questions about human conditions and diseases related to this topic. A semantic web/concept map and student created diagrams constituted an alternative assessment.

After five inquiry-oriented content courses Basic Science Minors move on to Experiences in Elementary School Science and Integrated Activities in Mathematics and Science. Both of these courses are open to others besides Basic Science Minors but are mostly inhabited by Basic Science Minors because of the prerequisite of four science courses. The courses are taken one to two semesters before student teaching and frequently one of them coincides with the required Teaching Elementary School Science methods course taken by all elementary education majors.

Experiences in Elementary School Science is two credit hours with three contact hours and is basically a pedagogical content knowledge course (Lee, 1993). It fits Borko's (1993) explanation of pedagogical content knowledge as content knowledge, pedagogy, knowledge of students, and knowledge of curriculum, integrated in a manner such that the whole becomes greater than the sum of the parts. Students are involved with in-class activities employing conceptually-oriented models, inquiry teaching, and authentic assessment strategies followed by reflection upon what was done, how it was done and why it was done. Teacher practitioner journal articles provide support reading or controversial food for thought for discussions. Field experiences involve on-campus teaching of elementary students as well as classroom teaching - all experiences include the planning and teaching of multiple learning cycle-style science lessons.

The course title Integrated Activities in Mathematics and Science somewhat describes the course. Curricular materials such as AIMS, GEMS, TIMS, FOSS, etc. are utilized with students to facilitate an understanding of how mathematics and science can fit together and how teaching one can enhance teaching the other. This class currently meets three hours a week and includes the assembly of a student folio of integrated mathematics and science lessons.

The last phase of this program is the student teaching component of the university teacher preparation program. For the Basic Science Minors, there is an attempt at placement during a portion of the student teaching semester with a cooperating teacher who is strong in science teaching and is oriented toward hands-on, minds-on science. During the funding period of the PEMST project over 130 K-6 teachers across the state of Iowa received in-service as a special cadre of cooperating teachers with background in pedagogy compatible with the mathematics and science preparation program. Some of these teachers still act as cooperating teachers.

Program Success

The benefits of this program are many and can best be provided by two graduates of the program. The first was among the initial group to matriculate through the program in 1991.The program was "new" enough that she did not even take all five of the content courses. The second graduate has gone through the program at a time when years of experience has allowed faculty to redefine and refine courses. She graduated in December, 1999 - the 10thanniversary of the first Investigations course.

1991 Graduate's Comments

As a graduate of UNI in December of 1991 I experienced a majority of the program. I student taught with a mentor teacher who participated in the PEMST teacher mentoring workshops and she was very supportive of my ideas and methods for teaching science.

I substitute taught and secured my first full-time teaching position in the Fall of 1992, where I taught science to students in grades 3-8. During this experience, I was very dedicated to teaching science the right way and in my mind, there was really only one way - that was to use a learning cycle, inquiry approach. During this first year my principal would often visit my class. She occasionally expressed that the type of excitement and involvement shown by the students in my class wasn't readily apparent in other classrooms in the building. I was shocked because I wasn't doing anything “special”. I was just doing what I knew and as far as I knew, this was “normal”. Later, when I resigned from that position, she asked me for a contact person at UNI to find another teacher, in her words, “just like you”.

The next two years were spent in a5/6th self-contained classroom where I taught my own language arts and math and all of the science. This was very exciting because I got to spend more time doing what I really wanted to do - teach science! Though it was my favorite part of the day I quickly sensed this was not the common feeling among my peers. My fellow 5/6th grade teachers were relieved I taught their science and the other teachers in the school were very reluctant to teach science at all. This was the first time that it occurred to me that perhaps I was somewhat different in how I felt about teaching science. Was it something different about my teacher preparation or was it that I had any preparation at all? I wondered what my fellow science minor graduates were doing in their teaching and if they too were feeling different than most of their colleagues.

When I returned to graduate school at UNI in 1995 my curiosity about my peers led me to do follow-up research on the Minor. I wanted to know what happened to graduates of the program. Were they having experiences like mine? What I learned was that generally speaking the other graduates interviewed in my study agreed with me. They too saw the program as a positive experience that has carried over into their experiential-rich classrooms. They remember many hands-on experiences combining content and process. They remember many of the things that they did and they now do them in their own classrooms. While they too shared many obstacles in implementing activity-based programs, they continue to be committed to what they were taught. They feel different than many of their colleagues. They actually teach science and they are excited about teaching science.

1999 Graduate’s Comments

As a graduate of UNI in December of 1999 I experienced the entire Basic Science Minor. The experiences were very valuable to me. The question “Am I different?” hadn’t really occurred to me yet, except now for this presentation. One answer would be “no”. My hair is not green nor is anything else noticeably different about me. Another answer would be "yes". When I teach science I think maybe I am different and I think that will impact me in my future teaching position.

First of all I am different because of the consistency of the program. The methods used in each coursed don't depend on the professor. All classes are taught from the constructivist perspective using learning cycles. The science courses are all set up in similar fashion with an inquiry orientation through hands-on activities and discussion. These professors make you do it, rather than tell you. The science content is relevant and I can see the use for either the knowledge or the actual activity in the classroom. And, they are demanding. They force you to think! Second of all I am different because the experiences in the program are not a tedious waste of time. You are encouraged to use all that you know. You actually experience constructivism at work.

How will this science program help me? It will make it easier for me to implement a constructivist learning model because I've seen it done, and I've been on the receiving side as a student. Now, after student teaching, I have been on the teacher side, doing it. Also, I have become cognizant of other teachers' methods. Wait time sticks in my mind (one of my science teachers could wait "forever"!). It is so important when doing inquiry teaching.

This program has made me excited about teaching. My goal is to promote lifelong learning and to do this I believe we need to get the students to think which will build the confidence they need to succeed. One thing that has become almost innate in me is that I want to do all I can for the students. I've seen times in schools when this is not the case. I feel strongly about changing education, rather than just participating. I know this isn't the easiest road. I know I will run into people who don't feel the way I do about teaching science. But that's OK. I will do it anyway!

Closing

While it would be desirable for all future elementary teachers to have this type of science preparation, that is not possible. What the Basic Science Minor does is prepare a small group of elementary majors per year with a strong content background, the pedagogical tools to teach inquiry-oriented science, and an attitude and orientation towards science and teaching science that serves them well as future elementary teachers and allows them to develop leadership in elementary science teaching. As Wallace and Louden (1992) state, teaching is complex, it is not a matter of applying skills, it is a product of professional knowledge arising from years of experience. The "genesis of teachers knowledge is in their practice" (pp. 519). Likewise, the genesis of preservice teachers notions of teaching and of science is in their experiences with learning and teaching science. The Basic Science Minor involves a different set of experiences from those of the past and hopes for the evolution of a different type of practice in the future.

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Appendix

BASIC SCIENCE MINOR for Elementary Education Majors

Course Descriptions

820:031	Activity-Based Physical Science (4 hr.) An activity-based introduction to concepts and processes in physical science using science process and models as a central themes. Lecture/discussion,2 periods; laboratory, 2 periods; plus 1 hour arranged.
820:032	Activity-Based Life Science (4 hr.) An activity-based approach to the diversity of living things, their lifecycles, and how they obtain energy and maintain energy flow through organisms and ecosystems. Lecture/discussion, 2 periods; laboratory, 2 periods; plus 1 hour arranged.
820:181	Investigations in Physical Science (4 hr.) Provides an introduction to concepts and theories of physical science and a model of effective teaching strategies related to the elementary level. Topics include energy, waves, mole relationships, solutions, acids and bases, electricity. Discussion and/or lab, 5 periods.
840:181	Investigations in Life Science (4 hr.) Provides an introduction to concepts in life science and a model of effective teaching strategies related to teaching elementary school science. Topics include structure and function from cellular to organism level, human biology and plant systems. Discussion and/or lab., 5 periods.
870:181	Investigations in Earth Science (4 hr.) Provides an introduction to concepts and theories of earth science and a model of effective teaching strategies related to the elementary school level. Topics include geologic materials and the processes acting on them and fundamentals of earth history, weather, and astronomy. Discussion and/or lab, 5 periods plus arranged.
820:130	Experiences in Elementary School Science (2 hr.) Develops understanding of science as an investigative process and how this relates to an inquiry approach to

lain elementary science teaching. Includes seminar discussions and field experiences in applying knowledge of science content and pedagogy to working with elementary level students. Discussion, 3periods.

210:141 Integrated Activities in Elementary School Science and Mathematics (3 hr.) Experiences with activities based on pedagogical strategies and the use of manipulative materials used in elementary science and mathematics followed by critical analysis of the application of these activities. Discussion, 3 periods.

210:161 Teaching Elementary School Science (3 hr.) Investigation of current textbook series, trends, teaching materials, and appropriate instructional strategies for contemporary elementary school science programs.

Note: All elementary education majors take this elementary science methods course. It is not included in the Minor.

820:140 Environment, Technology and Society (2 hr.) Emphasizes the relationships and interactions of the physical, biological, technological, and cultural components of the environment. Selected interdisciplinary problems are studied. The course builds upon the previous university experience of the student and seeks to develop environmental literacy.

Note: All elementary education majors take this capstone course. It is counted as a content course, but it is not part of the Minor.

ELECTRONIC CONCEPT MAPPING AS A PROFESSIONAL DEVELOPMENT FOCUS FOR HEALTH SCIENCES AND TECHNOLOGY ACADEMY (HSTA) TEACHER-PARTICIPANTS

James A. Rye, West Virginia University

Concept Mapping and Technology

Concept mapping as set forth by Novak and colleagues (e.g., Novak & Gowin, 1984) encourages critical thinking about and explicating concept interrelationships (Dorough & Rye, 1997, Jonassen, 2000). The concept map can be utilized to facilitate inquiry-based science and is especially suited to science instruction (Novak, 1990, 1991). Further, concept mapping can be employed to facilitate collaborative learning (Roth, 1994, Roth & Roychoudhury, 1994), to tap creativity, and to represent and communicate to others "what I know" (Jonassen et al., 1993). Science education research on teaching and learning has revealed numerous and promising applications (Wandersee et al., 1994).

A recent nationally representative survey of public school teacher reveals that only about 20% feel well prepared to utilize educational technology (Lewis et al., 1999). Electronic or computer-based concept mapping provides a tool to facilitate teacher literacy in information and instructional technology (President's Committee, 1997). Software is now available that allows learners to construct robust multidimensional concept maps, alternatively known as semantic networks (Jonassen, 2000), unconstrained by page size. Additionally, the ability to create concept maps electronically removes the drudgery of the erasing, recopying, and so on that inevitably accompanies paper and pencil based mapping: "The advent of computer-based concept mapping to foster knowledge representation and construction is an exciting technological advance" (Anderson-Inman & Zeitz, 1993, p. 9). Anderson-Inman and Zeitz (1999) contend that these electronic innovations have "greatly enhanced teachers' and studen willingness to use concept mapping for instructional purposes" (p. 7). Electronic concept mapping, as a critical thinking tool, contributes to the use of computers as "mindtools for schools" (Jonassen, 2000).

Fit of Concept Map with Science Enrichment Setting

The author has found the concept map to be an excellent tool in Health Sciences and Technology Academy (HSTA) programming, which provides extracurricular academic enrichment and career experiences (health sciences and secondary science teaching) to minority and financially disadvantaged secondary students in West Virginia. Over 80% of the 20 West Virginia counties/school districts that participate in HSTA are "high poverty" (≥ 50% of students eligible for free or reduced price lunch). Capturing student interest and commitment is a real challenge (Rye, 1998). Accordingly, HSTA needs to provide opportunities/vehicles for students to be creative and build self-esteem. Concept map construction fosters creativity and end products can be used to "show-case what I know."

HSTA programming, described in detail by Rye & Chester (1999), includes a summer campus component and a school-year community component. Secondary science teachers who participate in HSTA are "the most critical learning resource" for HSTA students, and accordingly, HSTA maintains a strong teacher-professional development thrust (Bardwell et al., 1999, Rye, 1998). This thrust interfaces substantially with the course work needed to earn a Master's degree in secondary science teaching, and 16 teachers have earned their Master's degree through HSTA participation.

The concept map is especially conducive to extended investigations (science projects) where HSTA students connect science to health and local environments (Rye, Bardwell, & Hu, 1999). These "authentic investigations" are conceived and carried out through "after school"

HSTA clubs utilizing a student centered instructional methodology known as the 3 Ps: problem posing, problem probing/solving, and peer persuasion (Peterson & Junck, 1988, Rusbolt, 1994. In particular, students can utilize concept mapping to develop an understanding of the science that underlies the "problem" they have posed and intend to investigate (e.g., nitrogen oxide emissions that compromise air quality). Further, the concept map can be used to communicate to others what was learned through an extended investigation, and accordingly, is a vehicle for "peer persuasion."

Former and current organizations that fund HSTA, such as the W. K. Kellogg Foundation and a National Institutes of Health Science Education Partnership Award, are especially concerned with transfer by HSTA teachers of instructional tools and strategies learned through HSTA to their regular school classrooms. As a constructivist-based tool (Jonassen & Marra, 1994) that supports meaningful learning (Novak & Gowin, 1984) in an electronic environment, the concept map holds considerable potential to enhance teachers' classroom instruction.

Initial Use of Concept Map Tool in HSTA

The author's previous experience in a teacher-leader institute that employed the concept map in "investigation level" Science-Technology-Society instruction (Rubba et al., 1995, 1996) informed the use of this tool in HSTA teacher-professional development. The concept map was introduced to HSTA teachers through a summer institute in 1996, where teachers teamed with post-secondary science educators to facilitate on-campus concept mapping experiences for HSTA students. The latter engaged students in constructing (paper/pencil) maps of what constitutes "junk food" as well as to showcase what they had learned from mini-research projects in neuroanatomy. A Fall, 1996, graduate course offering to HSTA teachers continued the opportunity to apply concept mapping, and high interest amongst teachers supported the continued use of the concept map tool in the 1997 and 1998 HSTA Summer Institutes. Rye (1998) provides descriptions of HSTA teachers use of concept mapping, such as this teacher's efforts at adapting the tool to a high school chemistry class: "It was the best application I've come up with to date. . . .It was one of those successful days that makes teaching worthwhile" (p. 12). The 1998 Institute introduced a subset of HSTA teachers (about 25) and "first year" (rising to ninth grade) HSTA students to computer-based concept mapping using Inspiration™ software (Inspiration, 1999), where concept maps were constructed surrounding a collaborative "community-based" project opportunity: monitoring ultraviolet-B radiation, and connecting the latter to ozone layer depletion and human and environmental health (Bardwell, et al., 1999). Inspiration is "visual learning software" that has many features, e.g., diagram and outline views, templates for a variety of graphic organizers, hypertext and hotlinks, robust picture library for science and other disciplines, and exporting graphics for use in other documents, presentation programs and web site construction. (For example uses of Inspiration by HSTA teachers and staff, see "Concept Mapping" at the HSTA web site: http://nt-hsta.hsc.wvu.edu/health.)

Evaluation of HSTA summer institutes and community-based programming from 1996 through 1998 has documented consistently that teachers intentions to use concept mapping are as great or greater than for all other tools or resources (e.g., the 3 Ps, the Internet) to which they have been exposed. Additionally, in a Fall, 1998 follow-up survey, 74% (*n* = 30) of teachers responded "4" or "5" (where 5 = a lot) to the query, "How much to do you use concept mapping in your classroom?" These findings, coupled with the need to enhance teachers' preparedness to use educational technology, served as the stimulus to expand teacher professional development in electronic concept mapping.

Electronic Concept Mapping Thrust

In Fall, 1998, a proposal, "The Concept Map as a Versatile Science Education Tool," was submitted to the West Virginia Eisenhower Professional Development Program. Most importantly, the proposal sought to fund site licenses of Inspiration for approximately 20 schools in which HSTA teachers were employed. Participation by HSTA teachers in the proposal was voluntary, and conditions of participation would require effort beyond their responsibilities in HSTA. These conditions asked teachers to complete additional professional development on electronic concept mapping, and to provide inservice sessions on project software (Inspiration™) and applications that they developed to other HSTA teachers as well as colleagues at their school of employment. The project was funded and initiated in early 1999, and the majority ($\underline{n} = 18$) of teachers who were exposed to the Inspiration software at the 1998 HSTA summer institute opted to participate. Principals of schools from which teachers were participating were appraised of the value of the software and expertise that these teachers would be "bringing in" to their schools.

Foci of Inquiry

This project took the form of applied research. It can be viewed as a case study on teachers' adoption of an educational innovation: electronic concept mapping, and more broadly, the visual learning tool Inspiration™. The author/researcher was the project director and also served as a curriculum coordinator for the teachers and instructor of a graduate course that was available to project participants. One focus of inquiry for this project was, "What applications will emerge for electronic concept mapping in science enrichment and science classroom settings?" Teacher participants will be engaged in developing and field-testing these applications, and this fits well with the National Science Education Standards (National Research

Council, 1996) professional development thrusts of "Inquiry into teaching and learning" (i.e., teacher as researcher) and "Teacher as a producer of knowledge about teaching" (p. 72).

The related foci of inquiry pursued by the author included: (a) What ideas for applications of electronic concept mapping will emerge from teacher dialogue through a Web-Board (Web Board by O'Reilly, 1998) supported forum?, (b) For HSTA students who use Inspiration to plan or present science projects, do they perceive they learn more from their projects than HSTA students who do not use the software?, and (c) In schools in which the Inspiration software is placed, what number of teachers choose to attend the workshops provided by HSTA teachers, and what are HSTA teachers' assessments of the value/outcomes of these workshops?

Core Workshop and Follow-up Support

As described above, most teacher-participants already were experienced with applications of the concept map tool and had surface exposure to Inspiration software. A one-day workshop was completed in early March, 1999, by all 18 participating teachers to extend their understandings and skills relative to hierarchically framed concept maps and use of the software. This included: (a) theoretical underpinnings, such as Subsumption or Meaningful Learning Theory (Ausubel, et al., 1978, Novak, 1992); (b) types of and vocabulary for concept relationships, such as cause and effect, temporal, quantitative, and properties (Jonassen et al., 1993); (c) uses of the concept map tool for presenting science projects and collaborative learning (e.g., negotiating understandings); (d) features of and practice with Inspiration software; and (e) electronic construction of a concept map for a topic that they teach. This one day workshop served as a model and resource: Participating teachers could utilize any of the handouts or content to plan and provide their own inservice for colleagues at their school of employment.

Follow-up support was provided in the form of a multi-station (20 to 55 computers) school site license for Inspiration, and correspondence and conferencing with the project director and teacher colleagues via email, electronic bulletin boards, and electronic chat rooms. The majority of teachers received additional support through attending a summer institute and a fall workshop and completing a graduate course that included a focus on the software.

Data Sources

The workshops and summer institutes were evaluated via questionnaires by the West Virginia University Office of Health Services Research (OHSR). OHSR also administered a questionnaire to HSTA students in mid-April, 1999, after presenting their science projects at the 1999 (April) HSTA Symposium. Additional data sources available relative to the foci of inquiry were: (a) electronic correspondence with project director and teachers (email, bulletin board postings, chat room transcripts), (b) Inspiration applications in lesson plans by teachers, (c) evaluations by classroom teachers who were inserviced by HSTA teachers, (d) reflections by HSTA teachers on the inservices that they led, (e) graduate course assignments, (f) a Participant Survey by the Eisenhower Professional Development Program State Office, (g) PowerPoint presentations by teachers, and (h) letters of support from teachers for refunding the project.

Findings and Project Accomplishments

Teachers emerged from the core workshop with considerable enthusiasm for the software, as evidenced by their responses on the OHSR questionnaire. The mean rating (1-5 scale, where 5 = a lot) by teachers on how useful the software would be for classroom use was 4.8 (*n* = 18) and for HSTA club use 4.4 (*n* = 16). Twelve (about 2/3) of the teachers planned to use the software to help students map out their HSTA science projects, and eight to help students organize research. On the OHSR post-symposium questionnaire, 71 students (22% of all responding) reported using the software to assist them with their science projects. All students were asked to rate (1-5 scale, 5 = a lot) how much they learned from working on their science projects. The mean rating by students who did or did not use Inspiration was 4.34 and 4.03, respectively. The Wilcoxon 2-Sample test revealed a statistically significant difference in favor of those using Inspiration (continuity-corrected Z score = 2.325, $p = .02$). Examples of project topics in which Inspiration was used included forensic science, ultraviolet-B radiation, anti-bacterial soaps, and asthma. Several students exported Inspiration documents into PowerPoint presentations of their science projects. Given that there was less than 2 months between the core workshops and the presentation by students' of their projects, it is expected that next year considerably more students will utilize the software for science projects.

An inspection of electronic bulletin board dialogue by nine teachers (about 50 posts, excluding those made by the project director) revealed that teachers were (a) developing novel ways to facilitate student competence in the use of Inspiration, (b) using the embedded notes feature of the software to develop study guides for students, (c) integrating the use of Inspiration with embedded assessments and with Internet research, and (d) engaging students in teaching and presenting to each other using Inspiration documents. Several categories and typologies emerged from inductive and logical analyses (Patton, 1990) of the postings: (a) Linking words are a difficulty in concept map construction by students; (b) Students enjoy electronic concept mapping; (c) Inspiration is a valid presentation tool for students; (d) Concept mapping is an important vehicle for collaborative learning; (e) Students "catch on" quickly to computer technology; and (f) "Buy in" by other teachers in my school is important to the use of Inspiration by students in my classes. Four excerpts from teachers' postings that illustrate specific uses of Inspiration and provide support for emergent typologies are shown below:

> My chemistry II students were so taken with Inspiration that they are now creating their own lecture notes. They are working in small groups to create a concept map chocked full of notes for a subsequent chapter. . .[and] plan on sharing them with their classmates
>
> I go along with Tresa's reasoning. If the kids are having fun they will learn more. Perhaps we could have them divide material into chunks and let groups do parts. . . .They then could combine maps and defend their presentations to other groups. I think we might be surprised at how much they might learn. I intend to do this instead of a traditional review before a test and see how it works.
>
> This was the first time I have been able to get an entire class on Inspiration at once, so it was great to see that they were running with it. I had found that when maps were done on paper, the students tended to forget to use the linking words. But on computer, it was easier to recognize that they were missing. Also, the appearance of the dialogue box on the line helped them to remember.
>
> Don't you wish we could learn to do all the things with computers as easily as the students? Most of them tend to just want an introduction, let them test it awhile and then ask questions only when they do not understand how to do something.

Electronic bulletin boards fostered a collaborative culture and community of learners in this project. Three excerpts taken from one "threaded discussion" serve as an example and support further certain emergent typologies listed previously:

> When they saw the map I had made of "Blood" I heard comments like "This really helps" and "I wish you would have given us this before now." My concern is the time involved using the software compared to. . . paper/pencil.
>
> It does take a lot of class time. . .but just think of how much fun students are having. . .they learn it much better. . .[and] you are meeting technology IGOs. You can also complete more subjects by breaking students into groups. . .research the topic, make the concept map, and present. . .to class. [T]he students have become involved in their own learning.
>
> Julie, I think that mapping goes much more quickly and with less stress using Inspiration. . . .[S]tudents who have been using it have decided it is easier to use because. . . most of their aesthetic worries are dealt with.

The lesson plans that applied Inspiration software/concept mapping, which were submitted by participating HSTA teachers, targeted the following: (a) developing competence and confidence in software use/study skill development; (b) planning of science projects; (c) preassessment and assessment, using Rapid Fire™ and hypertext features of the software; (d) lecture aid and study guide using hypertext features; (e) pre-lab/lab procedures for chemistry; (f) designing pedigrees to illustrate family traits; (g) designing concept maps from seed concepts and Internet research; and (h) using concept maps to teach peers. The last two applications were a part of a lesson developed and field-tested by one HSTA teacher who also participated in West Virginia Department of Education/IBM Reinventing Education: A partnership that provides an on-line environment for instructional development. This lesson can be accessed through http://reinvent.k12.wv.us. Once at this site, enter as "Guest," select Best Practices, scroll to "Grade 9 Science," and select the lesson "The Burning Question--UV-B and You." To see the concept map applications, go to Activity 1: What's in those rays?

The HSTA teachers provided inservice sessions to subsets of their HSTA teacher colleagues (about 45 teachers total) on the above lesson plan applications during the 1999 HSTA Summer Institute and Fall workshop. Eleven of the participating teachers reported that they provided an Inspiration inservice to their colleagues (over 140 individuals) at their school of employment between December, 1998, and November, 1999. Of the 11 HSTA teachers providing the inservice, 6 stated that they would be providing a second inservice due to considerable interest in their school. Most HSTA teachers administered a standard evaluation questionnaire at the end of their inservice, which asked the teachers who were inserviced to provide their rating (1-5 scale, 5 = excellent/a lot) of the utility of the software and how much of the inservice would be useful in their classroom teaching. Teachers rated highly the utility and potential for classroom teaching, which, respectively, were as follows: $M = 4.6$, 94% rated "4" or "5" ($n = 109$); and $M = 4.3$, 86% rated "4" or "5" ($n = 105$). The most common anticipated applications of the software reported by teachers were "organizing" and "outlining."

In their follow-up reports to the project director about the inservice sessions that they provided to school colleagues on Inspiration, HSTA Teachers' were in agreement that the inservice activities "went well." Excerpts of teachers reflections were as follows: (a) "It's an easy program to teach, since once you get them hooked, they seem to fly with it." (b) "The teachers did very well for their first time: They felt their students could also be successful;" (c) "More teachers signed up for this inservice than for any other choice;" (d) and "Teachers in attendance had seen Inspiration maps before due to spill over from my class." One HSTA teacher quoted comments he heard from teachers that he inserviced, e.g., "Give me more training and I'll be able to use this in everyone of my classes."

The Participant Survey from the Eisenhower Professional Development Program State Office was returned by 12 of the 18 HSTA teachers (67% return rate) who attended the core workshop and had software installed at their schools, i.e., were the major "grant participants;" and by 13 of 26 other HSTA teachers (50% return rate) who received a lesser amount of exposure to Inspiration/concept mapping. Ratings of knowledge and skill gained (1 = Not at All to 4=Very) by the grant participants and other HSTA teachers were, respectively: $M = 3.8$ (~80% chose "4"); and $M = 3.5$ (~50% chose "4"). These ratings and written comments about how the software was used (e.g., access prior knowledge, visual for lecture, note taking, presentations, review and test preparation) was consistent with other data sources: They verified the extensive and versatile use of the software and that participants valued highly the project/software.

Teachers who enrolled in a Spring, 1999, graduate course offering that included a focus on the Inspiration software were asked to write a "HSTA Club Impact Paper" in which they provided highlights and reflections about what they learned from facilitating HSTA club experiences during the semester. One teacher singled out Inspiration as the major impact:

> If I had to pinpoint one experience that impacted not only the HSTA club, but also my classroom, it would have to be the introduction of the Inspiration Software. This is a very valuable organizational tool. It has the ability to appeal to students who need visual pictures to learn and to those students who need traditional outline form to organize their thoughts. I have learned students at the high school level need very little instruction in learning the "nuts and bolts" of a program, just give them the basics and let them go.

In Fall, 1999, the project director sought funding to continue this project for the year 2000. Supporting correspondence received from HSTA teachers and their school administrators for the proposal increased substantially over that obtained for the initial (Fall, 1998) proposal: from 10 letters representing 5 school districts to 20 letters representing 13 districts. Excerpts from three HSTA Teachers' supporting correspondence follows: (a) "At my school, I think I am going to get it in as a formal part of the 7th and 8th [grade] curriculum;" (b) "Constructing their concept maps using Inspiration seems to be much more interesting for the students. . .and they are really proud of the finished product;" (c) "I have seen students use the program and come away with a better interpretation of the concepts because THEY were able to make the connections. I hope that I can use the program with all my classes in the future."

Triangulation of data from the different sources reported above leads the researcher to this assertion:

> HSTA teachers embrace electronic concept mapping, and more broadly project software, as a versatile educational tool. Factors contributing to HSTA teachers' enthusiasm include the ease with which students use the software, the transparent nature of the learning process to students engaged with the software, and the enthusiasm of colleagues whom they have inserviced on the software.

This electronic concept mapping project was refunded for the year 2000, and continuation will allow for the construction of a "web presence" at the HSTA web site (http://nt-hsta.hsc.wvu.edu/health). The use of project software will be integrated with modules being developed by HSTA teachers and staff through a National Institutes of Health Science Education Partnership Award. HSTA teachers are "positive" about their students using electronically prepared concept maps in presenting science projects at the year 2000 HSTA Symposium:

> [I] explained that Inspiration is a powerful presentation tool and that one of my goals this year was to help them prepare and conduct better presentations. Let them work for an hour on their own map. Total silence and focus. Wonderful.

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MODELING BEHAVIORS FOR YOUNG SCIENTISTS: VIDEO TECHNOLOGY AS A TOOL FOR MODELING INQUIRY SKILLS

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Modeling Behavior for Young Scientists

This project is exploring the feasibility of developing a mechanism by which elementary children will be given the opportunity to observe positive role models of appropriate children's behavior in a science classroom. The authors of this project have both recently returned from observing student teachers. It was evident that both preservice and practicing teachers were disinclined to teach science in a manner consistent with the hands-on/minds-on approach advocated by the American Association for the Advancement of Science (AAAS, 1989), the National Research Council (NRC, 1996) and the State of Illinois Learning Goals (Illinois State Board of Education, 1997). Their objections typically related the difficulty in establishing classroom behaviors that will enable children to participate effectively in a classroom where individual autonomy, freedom and manipulation of materials are the norm (King, Shumow, and Leitz, in press).

When teachers are asked to comment on why they are reluctant to have children manipulate materials in a hands-on science program, their responses typically include: discipline gets out of hand, children can't handle the freedom, it takes too much time, children can't work with other children, or it's too noisy (King, Shumow, and Leitz, under review). To address these obstacles to hands-on/minds-on science instruction, providing a set of model behaviors for students to emulate would do much to address the needs of both teachers and students.

Classroom teachers who were reluctant to have their students participate in a hands-on science program will show those images to their elementary students. By showing video images of young children engaging in appropriate behavior that is associated with inquiry science investigations, other children will then find a peer role model to inform their own behaviors. This project videotaped images of culturally diverse children engaged in different aspects of inquiry science. Documentation to support the use of these videos in the classroom was developed for use with the videotaped materials (King and Thompson, 1999a; 1999b; Thompson and King, 1999).

Current Literature

The attention to science as inquiry has been well documented through the last 35 years. During the last decade it has "resurfaced" in Science for all Americans (AAAS, 1989). This statement captures the thrust of the need: "In learning science, students need time for exploring, for making observations, for taking wrong turns, for testing ideas, for doing things over again..." (AAAS, 1989, p. 151). More recently, the National Research Council in National Science Education Standards (NRC, 1996) addressed a change of perspective for the promotion of inquiry in the science content standards section. Greater emphasis will be placed on: activities that investigate and analyze science questions; using multiple process skills--manipulation, cognitive, and procedural; using evidence and strategies for developing or revising an explanation; communicating science explanations; and doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of science content.

Locally, 1997 was marked by the arrival of Illinois Learning Standards, another document that supported an inquiry-based approach for science teaching. Goal 11A represents exactly the sorts of skills that foster an inquiry approach: the broad goal asks students to "Know and apply the concepts, principles and processes of scientific inquiry." Supporting sub-goals describe precisely those behaviors students need to demonstrate in order to become skilled in the process of scientific inquiry.

The importance of inquiry is clearly not under dispute. There is agreement that children should be actively involved in learning science. Therefore, to better engage children in an inquiry mode of activity, they should be given a better idea of what is expected of them. They need to observe the very behaviors we expect them to demonstrate. This is the essential value of this initiative.

The use of video media as a means of effecting change has many precedents. The use of films, videotapes, and more recently, videodiscs and CD ROMs has been used with students and teachers alike. Early films developed by Dwight Allen were used in microteaching settings to focus on specific instructional techniques. ASCD produced a series of Video Library of Teaching Episodes that could easily be used by professors with both preservice and inservice teachers. Encyclopaedia Britannica produced a series of Teacher Preparation Videos to accompany FOSS, their hands-on science program. These videotapes captured teachers demonstrating how the hands-on science activities could be conducted. They have been very popular, especially for teachers who are unaccustomed to the inquiry method of teaching science. In effect they provide the security of having a model to follow when they first try the activity with children.

One of the authors has recently completed the production of 10 videodiscs with four different audio tracks designed for use in both preservice and inservice teacher education. The set of videodiscs, documentation, and software has been packaged under the title Capturing Excellence, and was distributed to nearly 100 colleges, universities, and regional offices of education throughout Illinois. The interactive multimedia materials have been well received by educators for their value in providing positive role models for science instruction. Modeling has traditionally been viewed as one of the most powerful influences on teacher's behavior. The intention, through this project, is to develop "staff development" materials for the students themselves.

The basic premise for this proposal is simply to show children what hands-on/minds-on science looks like from a child's perspective. We know that such popular television shows like Sesame Street provide models that children and young adults emulate. If young children can be shown a video of other children demonstrating the behaviors and process skills that are recognized as being appropriate in a hands-on science classroom, they will have the means to emulate and engage in inquiry based science lessons.

This modeling approach finds substantial support from the literature. The work of Albert Bandura, among others, supports the notion that children learn and emulate behaviors modeled in their environment. Bandura's (1986) social-cognitive theory of learning states children learn by observing the behaviors of others and the social consequences of those behaviors. Real life models and symbolic models (seen through various kinds of media, such as video) can function effectively as models of behavior. Of particular importance to this proposal is the notion that children learn and emulate observed behaviors based upon two factors. The first are the characteristics of the model. The model must be believable and possess characteristics that the observer can replicate. The second is the child's ability to understand the observed behavior. The child must be able to interpret and comprehend the meaning of the observed behavior and the consequences of the behavior. This project addressed both factors by providing children role models that are essentially their peers. The children were able to observe peers modeling effective behaviors and be able to witness the consequences of those behaviors.

The intended outcome is that young children will be influenced by the exemplary behavior of children shown in the video segments. That influence will then be manifested when they engage in science activities. Teachers will benefit by reducing the potential for management concerns that commonly interfere with their willingness to engage children in hands-on science programs involving individual freedom, noise, movement, and collaborative ventures.

The second part of the project is to examine precisely what changes in student behavior emerged from the use of the video episodes. To investigate the precise nature of that outcome, classroom observations are currently underway, examining the effects of the videotaped episodes on student behaviors and classroom environment. A methodology to examine the instructional purpose of teacher-student interactions is currently being employed to examine the behaviors present in the classroom (Lehrer & Shumow, 1997; Shumow, 1998).

Connections with Scientific Literacy

A number of scientific literacy elements especially promoted in the state of Illinois were addressed in the development of this project.

The first represents the capacity to formulate questions; to seek, comprehend and use available information; to gather and interpret data; and to draw logical inferences in relation to an area of investigation. This project is in the process of producing and pilot testing videotapes containing real classroom examples of underrepresented children formulating questions, gathering and interpreting data, and drawing logical inferences. Children will have the opportunity to observe other young children doing science, as they will be expected to do. Picture a small group of second graders studying a topic like mealworms or physical changes where they ask questions, gather and interpret the data, and make inferences. By showing this short segment to a group of second grade children who are unaccustomed to engaging in science activities, their teacher can discuss the behaviors exhibited by the children in the video for the purpose of providing models for his or her students to emulate.

The second is the ability to comprehend and communicate the language, concepts, theories and practices of science, mathematics, and technology in ways that promote mutual understanding, cooperative problem solving, and shared vision. Children will be videotaped using language and concepts typically associated with quality science instruction. By seeing and hearing young children cooperatively working together on a common problem, other children less accustomed to collaborative behavior will be assisted in developing the very behaviors that we expect of them.

The final connection with scientific literacy is the awareness that science, mathematics, and technology are ongoing processes and growing disciplines, constantly evolving and being refined through inquiry and open-ended investigation. This aspect of scientific literacy is at the very heart of meaning of the nature of science. As a teacher educator I have striven through the years to communicate this aspect of science to preservice teachers. I have learned that modeling this aspect of science through the use of selected investigations and then discussing the kinds of observable behaviors of the preservice teacher was the most effective method to use to get students thinking about the nature of science. This project proposes a similar approach with young children. This pilot project suggests that if young children observe other young children participating in open-ended investigations and discussing their reasons for their ideas and hear them interpret the same evidence differently, they will be better equipped to demonstrate similar behavior in the future.

Project Content, Objectives, And Activities

As mentioned previously, the project is divided into two components: development of the materials and examining the effect of the materials made on student learning. These components will be considered here in detail.

Project Development

To accomplish these objectives, this proposal will involve the following activities:

1. Select four exemplary teachers who have demonstrated success with hands-on science instruction involving culturally diverse elementary-age children. Teachers will be selected who are currently working with children from Elgin School District U-46.
2. Conduct staff-development workshops for the exemplary teachers. The purpose will be to identify desirable behaviors and skills that can be videotaped, design appropriate activities for use in their classrooms, and develop the mechanisms for capturing those visual images. The staff development program will be offered, as a series of workshops in which the effective teaching strategies will be identified and the means for implementation in the classroom will be explored. University credit will be granted these participants at the completion of the workshops.
3. Videotape on location. Teachers and their students will rehearse the behaviors and skills in order to guarantee their capture on videotape.
4. Supporting documentation with will be written with suggested classroom use.
5. Distribution of the videotapes and supporting documentation will be made to the school district's primary teaching staff. The remaining copies will be distributed to selected districts/buildings wishing to implement the videotape program.

Project Content

The objectives of this project were the following:

1. Identify a set of common observable behaviors and basic primary skills that will be videotaped in order to provide role models for young children as they begin hands-on science programs.
2. Produce videotape for primary school teachers to use with their students for the purpose of providing appropriate modeling behavior for doing hands-on science activities.
3. Promote the use of inquiry based science instruction by modeling the behaviors associated with successful participation in inquiry based learning.
4. Provide supporting documentation for primary teachers containing suggestions for use with young children.
5. Investigate the impact of using the tapes on the classroom environment.
6. Distribute videotapes to elementary teachers in the Elgin U-46 School district as an aid to developing an inquiry-based science program.

To date, the first four steps identified above have been accomplished. Classroom observations are currently underway to examine the practices that have been influenced by the use of the instructional materials. Based on the findings of the investigation, suggestions will be made for the appropriate use of the video materials and their effective use in an elementary classroom. Broad dissemination of the materials will take place at that time.

Presently, three instructional videotapes and three instructional manuals have been produced. The videotapes and attendant manuals cover the following topics: classification, observing and inferring, and controlling variables.

A typical tape consists of the following sequence of events:

1. Introduction by the teacher--statement of a problem
2. Student cooperative grouping roles assigned
3. Students investigate the problem
4. Closure on the lesson.

At the transition between each step in the tape, a series of student "talking heads" comment on the tasks the students in the activity are engaged in. This serves to make transitions between different activities, as well as to make more understandable some of the more abstract (i.e., difficult to observe) aspects of the lesson. Typically, the classroom students end each set of video narratives with a question for discussion.

The teacher support manuals contain a synopsis of the lesson, commentary on the lesson, suggested discussion points related to the student-narrators, and two suggested activities to use to further develop understanding of the process skill.

A group of teachers interested in piloting the materials received a one-day workshop during the month of September 1999. These teachers will be involved in the subsequent evaluation of the project.

Project Evaluation

Year two will be devoted to data collection and analysis to determine the effectiveness of the videotapes. The immediate outcome of the project was the production of videotapes that demonstrate model behavior for classroom participation.

Baseline Data

A set of baseline data will be gathered at the start of the 1999-2000 academic school year. Eight classroom teachers will be invited to participate in the second phase of this Pilot Project.

Each teacher will receive a $500 stipend for his or her participation. The project staff will make classroom observations as to the state of inquiry based science practices. Student behaviors related to successful use of inquiry based science will be collected from eight primary science classes in the U-46 School District.

Assessing the Modeling Exercise

Eight classes were selected for participation. Four experimental conditions were assigned, with two classes in each condition. An initial (pre-treatment) observation took place for each classroom, and then three subsequent (in November, January, and March) observations during the remainder of the school year to seek evidence of any long-term changes in behavior.

Table 1.

Experimental conditions for project evaluation

Initial Observation	Video	Activities	Subsequent Observations
RO_1			$O_2\ O_{2'}\ O_{2''}$
RO_3	X		$O_4\ O_{4'}\ O_{4''}$
RO_5		X	$O_6\ O_{6'}\ O_{6''}$
RO_7	X	X	$O_8\ O_{8'}\ O_{8''}$

Children were videotaped during a "typical" science lesson before they were shown the videotapes and/or involved in the activities, to provide a baseline measure of student and teacher behaviors. The co-directors and graduate assistant are currently analyzing these videotapes. Data analysis will be completed to determine differences in observable behaviors between the two groups based upon the test group having received instruction with the modeling types and/or videotapes.

The co-directors will then conduct personal interviews with an appropriate sample of children and teachers selected from the experimental and control groups in order to verify any changes in their behavior associated with inquiry based learning. These findings will be analyzed and recommendations as to the use of video modeling will be forwarded to the partners in this project, Elgin, IL School District U-46 and the Illinois State Board of Education. Wider dissemination of results will follow.

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CONNECTING SCIENCE, SOCIAL STUDIES, AND LANGUAGE ARTS: AN INTERDISCIPLINARY APPROACH

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There is compelling research for connecting the curriculum across disciplines (Vars, 1991a). A connected curriculum has been shown to produce many benefits, for teachers as well as students. These benefits are: (a) Reducing duplication of both skills and content allows teachers to teach more, (b) integration connects subject areas in ways that reflect the real world, (c) higher level thinking and decision-making skills are practiced, and (d) the relevance of the curriculum is enhanced significantly (Vars, 1993). Educators are looking for ways to help students make sense out of the multitude of bits and pieces of knowledge being taught in our schools. It is my belief that when students are able to integrate the knowledge and skills they learn in all of their subjects, their understanding becomes deeper and more comprehensive. By seeing the connections in learning students can understand that what they learn in school will have practical value to them in their lives outside of the classroom. Gordon Vars (1991b) observed that "to lessen some of the fragmentation, various types of integrative or holistic curriculums are being proposed, including the distinct form of 'core curriculum' " (p.14). The purpose of this study was to observe and document how successful I, as the student teacher, andc first author, would be in implementing an interdisciplinary approach to teaching science, social studies, and language arts in the upper elementary level as evidenced by students' success in meeting content objectives and making connections between the disciplines.

Background/Theory

The concept of a core, or integrated curriculum has been evolving throughout this century.

One of the first and most significant studies on a core curriculum is the famous Eight Year Study of the Progressive Education Association (Aiken, 1942). The results of that study and nearly every study since then has documented that "students in various types of integrative/ interdisciplinary programs have performed as well or better on standardized achievement tests than students enrolled in the usual separate subjects" (Vars, 1991b, p.15). A holistic approach to teaching has gained in popularity as supporting research is completed. The National Council of Teachers of Mathematics (1995) issued a position statement that "K-4 teaching should center on interdisciplinary instruction derived from a curriculum organized around questions, themes, problems, or projects to capitalize on the connections across content areas. Furthermore, children need curricula which are more authentic, that is, reflecting real life" (p. 149). The Curriculum Task Force of the National Commission on Social Studies in the Schools (1989) stated "to assist students to see the interrelationships among branches of knowledge, integration of other subject matter with social studies should be encouraged whenever possible" (p.3).

The theoretical framework for this action research study is based on constructivism and interdisciplinary education. The term constructivism refers to an "internalization of information by the learner in personally meaningful and conceptually coherent ways" (Caine & Caine, 1991). There are several learning theories that support an interdisciplinary approach. In *Frames of mind: The theory of multiple intelligences,* Howard Gardner (1985) proposed that there are at least seven types of intelligence, and that people can have more than one type of intelligence. He argues that education has focused primarily on linguistic and logical intelligences at the expense of the other five. Caine and Caine (1991) cited research showing that the brain learns best when it works to solve problems or accomplish specific tasks instead of simply memorizing small bits of separate facts. An interdisciplinary approach to instruction encourages such problem solving. Resnick (1989) stated that people learn more successfully if they are asked to think in more complex ways, and are given several ways to look at a problem. An interdisciplinary approach can address all these learning theories.

As a result of the research supporting a connected curriculum, different approaches to implementing a connected curriculum have developed. In my experience teaching a thematic Kindergarten class, the first author observed that the more the students could connect the material being taught to information in their own lives, the more retention and comprehension they would achieve. Connecting the content seemed to be a crucial element of the lesson being successful. When the information I was presenting was more abstract and not related to the students on some personal level, the less interest they would show in the lesson, and their comprehension and recall were weaker. I also discovered that some disciplines were less conducive to being "fit" in a theme and as a result some of the depth of the disciplines would be lost in a thematic unit. Currently the various programs of a connected curriculum have been categorized into three basic approaches; integration, thematic, and interdisciplinary. These terms are defined by Lederman and Niess (1997) as follows:

> Integration refers to a combined or undivided whole where no clear distinction exists between the academic disciplines; thematic pertains to unifying or underlying commonalities among subjects or topics and tends to be broader in focus than integrated curricula; interdisciplinary maintains the integrity of the various academic disciplines, the distinctions between the disciplines remains clear, and connections between subject matters are emphasized (p.57).

The bulk of the research for an interdisciplinary approach is directed towards the middle school and high school years (Vars, 1991b). There is a strong movement in secondary education to incorporate interdisciplinary education, with much supporting research. But on the elementary level it is still the common practice to blur the boundaries of the disciplines in such a way that the individual distinctions of the disciplines are lost. But, if as stated above, to make higher level connections between the disciplines one must first have a knowledge of what comprises the identity of the disciplines, shouldn't we begin teaching the boundaries at the elementary level? It seems a logical transition that if research supports an interdisciplinary approach on the secondary level, we should lay the foundation for that approach during the elementary years. Thematic instruction removes the boundaries and makes it difficult to tell where one discipline leaves off and another one begins. It is based on this notion that I decided to implement an interdisciplinary approach at the elementary level, focusing on integration, but still having distinctions between the disciplines.

As stated above, I found thematic instruction to be limiting, particularly in the areas of math and science. According to Dickinson and Young (1998), "thematic units for an elementary classroom are developed around broad topics...when teachers use the thematic units from professionally prepared curricula they are actually teaching topics rather than science themes" (p.335). The same results were found when an integrative approach was used, in which the boundaries of the disciplines were blurred. Another result of the integrated curriculum was that the science goals or *Benchmarks* (AAAS, 1993) were not being met. At the elementary level it is necessary for students to be taught to recognize the various disciplines, and to develop a thorough understanding of the different disciplines of which without it is difficult to develop an integrated or interdisciplinary awareness of the connections between disciplines (Dickinson & Young, 1998). As a result of my teaching experience combined with my graduate course work, I became interested to learn if there was another possibility besides the thematic approach at the elementary level for successful integration of the disciplines that would not loose the nature of the disciplines. Research has shown that an interdisciplinary approach is beneficial for students reading below grade level (Gaskins & Guthrie, 1994), and gifted students (Vars & Rakow, 1992), as well as the average student. There is also strong research that suggests connecting reading and writing to the sciences and social sciences. "Merging these domains of science, history and literature can enable students to learn content and process simultaneously and create an intrinsically interesting context for teaching the cognitive and metacognitive aspects of reading and writing" (Gaskins & Guthrie, 1994, p. 1039). For this study, I implemented an interdisciplinary approach, with the focus on connecting science, social studies, and language arts. It was my goal to define the boundaries of the disciplines while showing the content connections between the disciplines.

Research Questions

The research questions I posed with regard to this topic were: (a) Would students see connections between the disciplines while at the same time recognize the individual disciplines and the skills and tools used for the particular disciplines, and (b) how successful would students be at meeting the objectives for each discipline as evidenced by their performance?

Project Implementation

Context and Participants

My research project was implemented throughout the duration of my thirteen week student teaching experience. The class I was assigned to was a traditional, fourth grade inclusion classroom (hereafter referred to as 'Class 16'). The experience started on January 4, 1999 and continued until April 2, 1999. Within this time frame I assumed full-time teaching responsibilities for a continuous period of six weeks.

The subjects involved in my project were the twenty-six children who comprised Class 16, their assigned homeroom teacher (Field Specialist) who instructed them in math and spelling, a fourth grade teacher who instructed them in science and social studies, another fourth grade teacher who instructed them in language arts, and myself (the student teacher).

The student population of Class 16 was considered diverse and challenging. Sixteen of the twenty-six students qualified for special services. The special services for which the students were pulled out of their classroom setting included speech therapy for five students, occupational therapy for one student, LAP(Limited Academic Proficiency) instruction for one student, Resource academics for three students, and intervention group counseling for five students as a result of alcohol and drug abuse in their families. In addition, there were six ESL (English as a second language) students, and two students who took daily medication for Attention Deficit Hyperactivity Disorder. Three of the students in the class, two boys and one girl, were on a district discipline behavioral plan, which meant that these three students are at risk of being expelled from school as a result of habitual poor behavior. There were ten girls and sixteen boys. The minority population consisted of six Hispanic students and one Native American student. The class had a wide range of ability levels, including one student who tested below kindergarten level, to one student who was performing on the eight grade level. The remainder of the class had ability levels ranging from first grade to fifth grade. Nine of the twenty-six students (35%) were working on grade level, and 15 students (57%) were performing below grade level.

My Educational Field Specialist was a teacher with ten years of experience in upper elementary and middle school. The other two teachers I worked with had a combined total of 37 years of teaching experience.

The classroom was located in a public school building that included grades K-5, with approximately 500 total students. The classroom was of average decor and ambience. The students sat at tables instead of desks, and were assigned classroom seats, from which they could not vary. All of the students' time was spent at their seats, with very few cooperative learning structures used. Except for a group word study half an hour lesson taught once a week, the work was all independent seatwork.

The intermediate structure at the school my study was undertaken in is referred to as Looping. There were six upper elementary teachers. Three teachers taught fourth grade for one year, and then moved up with their students the following year to teach them fifth grade, while the fifth grade teachers of the first year 'looped' back to fourth grade with a new group of fourth graders.

The participating school was a Core Knowledge Sequence school. A Core Knowledge Sequence is an elementary curriculum developed by Dr. E.D. Hirsch, Jr. and the staff of the Core Knowledge Foundation. The Core Knowledge Sequence is based on research to determine the content that every American student should know before graduating from elementary school. The Core Knowledge Sequence provides a systematic sequence of grade-specific content that can be taught consistently year after year. The core content is organized to spiral through the grade levels, becoming more sophisticated and detailed in each successive grade. It is intended to form the basis of an integrated instructional program and is not to be taught as an "add-on" during a special time period each day (Core Knowledge Sequence Foundation, 1995).

The fourth and fifth grade staff at the school in this study had developed a curriculum based on the Core Knowledge Sequence. There were strong attempts to integrate the content, but once reviewing the curriculum it was discovered that the integration was focused on social studies and language arts, with no connections being made from science and math to the other content areas. The school in this study had developed a school day schedule similar to the block classes at the middle school level. Each of the three fourth grade teachers taught two subjects. My Field Specialist taught the subjects of math and spelling, one of the other teachers taught science and social studies, and the third teacher taught reading and writing. The fourth grade students spent the morning with their homeroom teacher, being instructed in the two subjects their homeroom teacher was responsible for. In the afternoon the students would rotate to the two other classrooms for instruction in the other subjects, with time blocks of 55 minutes. The only exception to the schedule was for science and social studies. The teacher responsible for these two subjects did not teach them simultaneously, but would teach social studies for 4-6 weeks, and then teach science for 4-6 weeks. The three teachers were not satisfied with this current arrangement, and planned to change the schedule the following school year so science and social studies could be taught simultaneously, by two different teachers.

Procedures

Curriculum Development. To implement my project I needed to develop the interdisciplinary curriculum. I was given the curriculum for January through April with the understanding that I could deviate from the original time line to develop connections as I saw them. Due to a grant project involving Legos, the social studies teacher was behind the other teachers in the schedule. After reviewing the content to be taught for the next three months, I developed a curriculum that consisted of a combined unit in language arts on the genre of biographies. The unit began with an introduction to biographies with the students writing a biography of a partner or an autobiography. Several biographies were read and studied. The social studies component was brought in by instructing the students on four scientists: Benjamin Franklin, Samuel Morse, Thomas Edison, and Michael Faraday. The students researched one of the scientists and wrote a biography on their selected scientist. In addition, the social studies content included the American Revolution. The science content was a unit on electricity. The emphasis was on an interdisciplinary curriculum that left the boundaries of the various subjects intact, while demonstrating the connections between the subjects. There was no central theme for integration, but as seen in Figure 1, there were connections between the disciplines, or subjects.

Schedule. It was determined that I would be solo teaching for six weeks. The connected curriculum I designed would be implemented during this time, with the exception of the American Revolution. Due to the design of the classes, the electricity unit would be taught first, followed by the American Revolution unit. I began implementation of the interdisciplinary curriculum in week three of my student teaching experience. The schedule of instruction is represented in Figure 2. In addition to the curriculum, a classroom group discussion on the nature of science, social studies, and language arts was conducted every Friday in the respective class. A KWL chart was used for the discussions which the students copied down in their journals. The chart was referred to throughout the project and updated every week.

Figure 1. Venn Diagram illustrating connections between the subjects of science, social studies, and language arts.

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Figure 2. Time schedule for implementation of the interdisciplinary curriculum.

Week	Subject	Content
5	Language Arts	Biography genre
	Science	History of Electricity
	Social Studies	Introduction to Franklin, Morse, Edison, Faraday
6	Language Arts	Write autobiography
	Science	Introduction to Electricity
7	Language Arts	Research on scientist biography
	Science	Electricity experiments
	Social Studies	Research on scientists
8	Language Arts	Write biography on scientist
	Science	Electricity experiments
	Social Studies	Presentation on biography: Historical Context
9	Language Arts	Gulliver's Travels
	Science	Electricity Reflections
	Social Studies	American Revolution
10	Language Arts	Gulliver's Travels
	Social Studies	American Revolution

Data Collection and Time Line

To ensure the validity of my qualitative research, I collected data from a variety of sources as identified and defined below.

1. Initial Interview with Educational Field Specialist. This interview disclosed what instruction method the students had been exposed to in the first half of the year. I was looking at what integrated or interdisciplinary instruction, if any, the teacher had implemented. I asked my field specialist specific questions to determine her views on interdisciplinary education and what type of a core curriculum had been implemented in the classroom. The questionnaires were given face validity by a review of a team of experts. (Week 1)(Appendix A)

2. . Open Student Interviews. I interviewed five students from varying performance levels on their ideas of the various disciplines (science, social studies, and language arts). I was looking to see if the students saw any connections and real life applications among the disciplines. I interviewed these students at the beginning of my student teaching, and again at the end of my student teaching experience. (Week One and Week Twelve)(Appendix B)

3. Daily Observer Logs and Journal Notes. I kept a daily observer log noting the reactions and behaviors of the five students who were selected to be interviewed. I was looking for behaviors that represented the students meeting objectives and making connections between the disciplines. I also kept a journal of each days' events, noting my own performance and behaviors engaged in this project. (Weeks One through Twelve)

4. Students' "Connection Journals." Students kept journals in which they reflected on a weekly basis of any connections they saw between the content area introduced that week.

The journals were kept in the classroom, and the researcher reviewed them weekly. The students could use any form of written communication (narrative, lists, outline, illustrations) to demonstrate the connections to other content areas or to real world applications. (Weeks Three through Twelve).

5. Samples of Student Work. I collected and assessed samples of students' work as representatives of content taught and objectives met. I was looking at the success of the students on their work as evidence of objectives being met and the success of the interdisciplinary curriculum that was implemented. (Weeks Three through Twelve).

6. Teacher Record and Plan Book. I used my record book of grades recorded as a measurement of the students' success in meeting the objectives. I used my plan book to document the curriculum being implemented and to triangulate the other sources listed regarding the success of the interdisciplinary curriculum implemented. (Weeks One through Twelve).

Data Analysis

Procedures

A general screening of the six data sources listed above was performed to determine the success of an interdisciplinary curriculum as evidenced by students making connections and meeting objectives. A review of the data mentioned above determined what information there was relating to the students' success of meeting the content objectives through an interdisciplinary approach. In reviewing my data I was looking for trends or patterns that demonstrated students making real-life connections, and connections between the disciplines. I was also looking to see what impact the interdisciplinary curriculum had on their interest in the content being taught, in the development of their knowledge of the subjects of social studies, science and language arts, and in their success at mastering the content introduced in the interdisciplinary curriculum. I was looking for triangulation between the students' work, journals, and beginning and ending interviews.

Trends

The analysis of my data showed three prominent trends. The first trend was that almost all of the data directed towards students' awareness of connections between the disciplines showed students consistently seeing connections between language arts and science, and connections between language arts and social studies, but the students were not seeing connections between science and social studies. This was in relation to the second trend in that the data showed that students thought science and social studies were the same subject. As the students' exposure to the nature of the disciplines increased, so did their ability to make connections between the three subjects, with the exclusion of connections between science and social studies. Only one student in the class was able to make a connection between science and social studies at the beginning of the project. This number did not change at the close of the project as evidenced by the students' connection journals, class discussions, and questionnaire. The third trend I saw was that all data directed towards the students' performance in meeting the objectives indicated that when the students' interest was high in the content being taught and the real-life applications were more evident, the success rate of the students meeting the objectives of the content was a higher percentage for the distribution of the class. The success rate was determined by a grade of C+ or better for 92% of the class.

Discussion

Curriculum Baseline. Data collected during the initial interview with my Field Specialist, and from the questionnaire she answered, uncovered the fact that the Core Knowledge Sequence was used by the participating school. She shared that the fourth and fifth grade teams worked together to devise the current schedule, which was based on the core curriculum of Dr. E.D. Hirsch, Jr. My Field Specialist was not familiar with the interdisciplinary approach to content implementation, but she was informed on the thematic and integrated approach. She indicated that an attempt to integrate the subjects was made whenever possible in the curriculum. The emphasis of integration was on language arts with social studies, while math, spelling, and science were not integrated. My Field Specialist shared that there was some content that was indicative to being integrated, but other content that was not. This was based on an integrated curriculum, or one that had a general theme or topic, such as Medieval Europe. She expressed interest in an interdisciplinary curriculum and the fact that a unifying theme was not a necessary component, but rather connections were presented between discipline content or a common thread running through the various content areas.

Student Knowledge Baseline. I selected five students during the first week on which to focus my data collection. These students ranged in ability level from the second grade reading level to the eighth grade reading level. The data collected from the initial interviews and questionnaires of these students showed very little knowledge of the nature of the subjects themselves. In response to the questions regarding the nature of the subjects, all five members of the selection group could not answer the questions. There was an obvious lack of background knowledge of what science, social studies, and language arts involved. In addition, in the initial interview the selection group saw little to no connections between the subjects, and could only articulate real-life applications to the subjects of math and reading. It was found that the construction of the classes, with science and social studies being taught by the same teacher at the same scheduled time and being taught in seriation, confused the students to the fact that science and social studies were two separate disciplines. The data disclosed that 80% of the student population of Class 16 thought science and social studies were the same subject. This supported existing research on interdisciplinary curriculum that students need a strong foundation in the nature of the various disciplines or subjects before conceptual connections between the disciplines and the resulting real-life applications can be made. An interdisciplinary curriculum could strengthen the knowledge of the disciplines themselves by keeping the boundaries of the subjects intact, while at the same time presenting the connections between all disciplines and consequently taking those connections and applying them to practical, real-life circumstances.

Closing Interview With Student Group. The closing interviews and questionnaires evidenced a growth in the understanding of the nature of the three subjects; science, social studies, and language arts. The students demonstrated an improved baseline of knowledge about the substance of the three subjects. This was evidenced by students' responses on their questionnaires. Four out of the five control group students said "I don't know" in their initial response to questions regarding the nature of the subjects. All five students had accurate information to contribute regarding the subjects at the closing interviews. It is my assumption that this increase in knowledge was correlated to the group discussions every week on the definition and nature of the three disciplines. This element of the project was added when I realized how limited the students knowledge was in the basic subjects. As the students' knowledge of the disciplines grew with our class discussions, so did their capacity to make connections between the disciplines, and also their ability to make real-life connections to the curriculum. This was an interesting development that also supported research on an interdisciplinary curriculum.

Literature and Artifacts Related to Project. The Daily Observer Logs and Reflection Journal notes I took supported the trends I saw during my project. Nearly all of the notations indicated a weak background knowledge in the nature of the disciplines, and that very few connections were being made by the students, or real-life applications to the content being taught. One student's response, "science and social studies are the same thing, only their names are different," was indicative of the majority of the class. My journal notes and class artifacts evidenced some improvement in the students' understanding of the nature of the subjects at the end of the project, but there was still a majority of the class who had a weak understanding of science and social studies, with the percentage of students who thought science and social studies were the same thing dropping to 15% from 92%, but 80% of the students still had a difficult time in giving sound definitions of science and social studies. This seemed to signify that students need more interaction and instruction in the nature of the disciplines than thirteen weeks in order to grasp the complex nature of science and social studies. With very few exceptions, my journal notes showed that students' ability to see connections between language arts and science, and language arts and social studies, increased throughout the duration of the project. The students' understanding of the nature of language arts increased tremendously during the project. At the initial phase, 92% of the students couldn't tell me what language arts are, or even that they were in language arts class at the appropriate time. The data seemed to suggest that the students had not been exposed to the "labels" of education, and were unfamiliar with many of the terms used to describe the various subjects and disciplines.

The students' connection journals and academic work triangulated with the other data to show that the students had little knowledge in the nature of the disciplines at the onset of the project, and were making very few connections between the subjects and to real-life applications. The students' KWL charts in their journals demonstrated an increased knowledge of the subjects of science, social studies, and language arts. As the project developed, students were making more connections, possibly in connection to the group discussions once a week on the definitions of the subjects. The group discussions and corresponding KWL charts were added to the project after I observed how little background and understanding the students had in the subjects themselves. A more aggressive approach to educating the students on the nature of the disciplines seemed necessary in order to facilitate the students' success with an interdisciplinary curriculum. An example of the progress of one of the five students of the target group can be seen in his connection journal entries comparison. One of the first reflections of this student was "the people in language arts are all dead and electricity was invented a long time ago," to his final entry ten weeks later, "if you write a biography about a scientist in language arts, you are using reading and writing, and it is effecting science because you are learning about science and electricity while you write it." Of the five students in the control group, there was one who still was confused on whether there were any differences between science and social studies, and the interesting observation is that this student also had difficulty in making any connections between the subjects, and difficulty in making real-life connections to the content being taught.

The data demonstrated a high level of interest in the electricity science unit. The majority of the class, including the academically lower performing students, had success with the electricity unit as reflected in a grade of C+ or higher. The data did not show evidence to the reason for this success, but it can be assumed that the hands-on, real-life application of science was an entertaining form of learning for Class 16. The data from my journal notes, students' work and connection journals indicated that interest was highest in the electricity element of the curriculum. Triangulation was seen among the sources of data, with similar results being indicated in all sources of data.

Outcomes

The primary outcome I was expecting was that my students' exposure to an interdisciplinary curriculum would result in an increased awareness of the definitions of the disciplines of science, social studies, and language arts. I was hoping to see a high success rate of my students achieving the various content objectives. I was also expecting students to be able to make connections between the various disciplines and relate these connections to real world applications. I did see my students develop a stronger baseline of knowledge in regards to the nature of science, social studies, and language arts, but this was probably a result of direct instruction on my part, and not a natural outcome of the interdisciplinary curriculum. As stated earlier, I believe this was due to the complex nature of the disciplines, the limited knowledge the students brought to the project, and to the time restraints of the project. The success rate for students meeting content objectives was high and did meet my expectations, particularly in the science unit with a 92% success rate for Class 16. The language arts unit resulted in an 89% passing class score. The social studies success rate percentage for the whole class was an 85% passing grade. The success rate was not as high as I had initially hoped for in my proposal, but after learning the class dynamics, the scores were moderately higher than the typical grades of Class 16. The data showed that students were able to make connections between the disciplines, and this ability to make connections grew throughout the project along with the corresponding class discussions and KWL charts on the nature of the subjects; science, social studies, and language arts.

In a broader sense, I was expecting my students to have a high level of interest in the curriculum, and to take an active part in their learning. Except for the unit on electricity, in which interest was high, the students' interest seemed low in the language arts and social studies units. The electricity unit was a cooperative learning, hands-on curriculum with evident real-life applications. The language arts and social studies units involved a large writing component, and Class 16 did not like to write. In addition, Class 16's writing ability was below grade level. I believe that these were all contributing factors to the varying levels of interest the students demonstrated. The majority of the students did not take an active part in their learning, and were constantly looking for guidance and directions from myself in their learning process. It was an interesting observation that the more interest the students had in a unit, the more they were willing to work independently. Some of these behaviors could be attributed to several factors; that these students had very little exposure to cooperative learning, the dynamics of the personalities of the students, and having a new teacher.

My expectations were in alignment with professional research on interdisciplinary education and a constructivist approach to teaching. I was pleased with the outcome of my research and will continue my research into implementing an interdisciplinary curriculum.

Conclusions

Based upon the results of my project I have concluded that implementing an interdisciplinary curriculum is a challenging but important task. With the curriculum reform that is being currently undertaken in this country, an interdisciplinary curriculum should be considered an important part of that reform. I was surprised at the lack of knowledge my students had of the nature of the disciplines. It is my belief that for learning to take place, students need a frame of reference in which to analyze and identify new knowledge. In the short time this project was implemented, I saw my students develop a stronger foundation in the definition of the disciplines, and probably as a result they had higher academic achievement than they had been experiencing. I'll always remember the happy look on the face of one student, with whom I had struggled over behavior and academic performance, when I told her she had received an 'A' in both science and language arts. This was not a grade she was used to receiving. An important conclusion for me was that it takes time and consistency for students to understand the nature of the disciplines. My outcomes demonstrated very strongly to me the need for an interdisciplinary curriculum on the elementary level, and not just the middle school and high school level.

Teaching Implications

The constructivist theory on learning has been emphasized in teaching in the past decade. This has brought new life to the connected curriculum ideology of this century, and has put interdisciplinary education in the forefront of secondary curriculum evolution. If research continues to show that an interdisciplinary approach is the most effective of the various connected curriculum approaches at the secondary level, then researchers need to start addressing the elementary level and what implications an interdisciplinary curriculum has for the elementary student. From my research I concluded that an interdisciplinary curriculum could be implemented successfully, but it should be started at the beginning of the school year, with an emphasis on building a foundation of knowledge on the nature of the disciplines. Considering Class 16's lack of knowledge on the various subjects, their lack of exposure to an integrated or interdisciplinary curriculum, and their academic levels, the students made ground in their academic development with the curriculum I implemented. The promise of an interdisciplinary curriculum making instruction more interesting, applicable, and logical is excellent. Future research, I believe, should be done over the length of a full school year, if not longer, to get conclusive results. I hope to conduct additional research on an interdisciplinary curriculum in my own classroom. I believe that this approach would be the most effective at any grade level. It is logical that if higher level thinking and analysis results from making connections across disciplines, students need to know first what they are making connections to. I feel even more strongly now, after the completion of my research project, that I will be implementing an interdisciplinary curriculum in my own classroom. I can't imagine teaching any other way. I think the teaching implications are profound, and the connected curriculum will continue to gain momentum into the 21st century. Hopefully this momentum will begin to affect elementary curriculums as well as secondary curriculums.

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Appendix A
Education Field Specialist Questionnaire

1. Do you implement any form of integrated or interdisciplinary curriculum? Can you describe it?

2. What is your philosophy on connecting content areas?

3. Do you make any real world connections to the content being taught? What are some examples?

Appendix B
Student Questionnaire

1. What do you think the subject of science is about?

2. Do you like the subject of science? Why or why not?

3. What do you think the subject of social studies is about?

4. Do you like social studies? Why or why not?

5. What is your favorite subject? Why?

6. Do you think science and reading have anything in common? Why or why not?

7. Do you think science and math have anything in common? Why or why not?

8. Do you think science and social studies have anything in common? Why or why not?

9. Do you think what you are learning in school will help you in the real world when you grow up? Why or why not?

DISTANCE EDUCATION FOR NEWBIES

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Interactive compressed video has grown rapidly in eastern Kentucky because it is an easily accessible, cost-effective method for course delivery. Morehead State University (MSU) is a regional university that serves the Appalachian region of Eastern Kentucky. The lack of major highways and weather conditions in the region cause it to remain isolated. Aside from the usual mechanical needs of such a class, and the regular equipment updates, it has profited.

Distance education at MSU, which operates via a fiber optic telecommunications system, has grown from one class delivered to seven sites, Fall semester 1995, to more than 29 classes delivered to eighteen sites, involving more than twenty-three faculty members and six hundred twenty-two students. The university utilizes a fully interactive telecommunications system that provides full motion video (compressed) and audio transmission. On-campus and off-campus students interact using either voice activated microphone or a push-to-talk microphone. The instructor aided by a site facilitator at the origination site controls the delivery of course content and communication among sites by using a touch-controlled computer panel. All sites employ a site facilitator who operates the technology, acts as liaison between the students at the remote site and university faculty, and performs class management duties, such as taking attendance, distributing materials, and proctoring quizzes and tests. The instructor makes periodic visites to each remote site in order to establish personal contact with all students. Technologies present at each site include teacher and student cameras, a computer located at the podium for the use of the instructor, student computers, an overhead camera for display of class materials and a minimum of two monitors. All class transmitted are videotaped and make available to students.

Compressed video courses are housed in local schools and outfitted with computer stations and electronic podiums. A site facilitator is hired for each course to maintain the equipment and trouble-shoot as necessary. It was estimated in the Spring of 1998 that each class cost approximately $2,500 per site. A maximum of five sites are chosen with a cap of thirty students for the total class size. Each site must have a minimum of five students for the total class size. Each site must have a minimum of five students for a class to broadcast to their location. A traditionally delivered class to MSU's most distant site, which is a four hour one-way drive, would cost approximately $2,900. Such a course would enroll a minimum of eight students. Financially, more students would enroll in the compressed video course, the instructor would not visit the distance sites each week of the course, and university "mileage" costs would decrease. Additionally, students working and living in off-campus areas have commented that the compressed video courses have increased their recruitment and retention. Many of them live within range of other institutions, but choose to attend MSU because it is more conveniently located.

Compressed video is not the only distance learning option at MSU. We also offer Internet based courses delivered via the Internet Classroom Assistant called Course Info. Course Info is owned by Blackboard Inc. in Washington, D.C. It is a paid service with full benefits to members. If you would like to see a course, please feel free to contact me for additional information. Many instructors who use compressed video will also bring Course Info into their traditional classrooms as well as the compressed video classroom.

Using the resources at hand in these classes can be challenging. I have participated in many training sessions and have undertaken many other independent opportunities to learn multimedia programs. MSU offers training sessions in Course Info and the distance learning classroom. Instructor are taught how to use the electronic podium. It consist of an opaque projector called an "ELMO," sounds panels, camera panels, and computer controls. It is quite easy to get the hang of the podium while one instructs. Several advantages exist with the distance classroom. Among those are the frequent use of multimedia by instructors and students to illustrate focal points of the course, Internet and computer access to demonstrate ideas, and both opaque and translucent items can be used with the ELMO. The communications advantages are numerous also. Instructors can group e-mail students as well as vice-versa, students have ready access to periodicals and other courses materials without reliance on paper delivery, class discussions can be augmented through threaded discussion boards, students may produce web pages to demonstrate principles, feedback to instructors and students can be immediate, and finally, instructors can maintain virtual office hours! Some of the resources are challenging to students: sending e-mail attachments, reading files, and using the Internet effectively. The following paragraphs address the challenges.

Sending attachments is a sticky situation. If you have a PC and send to a Mac user, then the file is likely mime encoded. This means that the file is just a PC type. Mime decoders are available on the Internet for free. I downloaded mine from America Online. Should students send complex, format rich documents, it can be distressing to see all those lines of code positioned around the real document. Students will become very frustrated if this occurs! My suggestion is to always advise students to send either ASCII files or rich text format files. The RTF files will maintain most of the formatting whereas the ASCII is a text only format. If one has Microsoft Office 98 or Office 97, one can send files with the doc extension which will be read with all the proper formatting. Even if they are sending from a PC to a MAC or vice-versa.

The mime decoder works well for retention of format also. In fact, I've had few problems lately with formatting since many users have now opted for Word 97.

Once mechanics of the document are decided, sending the attachment is easily accomplished through the Internet browser. Depending on the browser, one will see the attachment button either on the toolbar in mail mode or on the e-mail itself. I will not attempt to describe each browser set-up. Several versions exist of the same browser and it would be easier to ask the technical wizards in your office to explain where the attachment button is located. If you have Pine e-mail, attachments can be complicated and I suggest that you speak with the information technology folks at your institution.

Reading e-mails requires a download of the file and opening it into the proper program. Most files will save on a PC at the "temp" folder on Drive C. If you have a Mac, then you can choose the location for download. Many browsers will offer the choice of download sites. If one is reading a PDF (portable document file) file, then it is necessary ot have the free reader. Go to http://www.adobe.com for the free software.

Effective use of the Internet is made much simpler if the instructor maintains a web page for student use. Teaching students how to use a search engine may seem passe', but one will soon find that students do not know how search efficiently. Give students information about Boolean searches and tips with specific search engines. It will increase their productivity and their enthusiasm. I also maintain a site with K-12 teacher resources. Since I teach preservice teachers, they must locate and use online resources such as periodicals, dictionaries, games, and download sites. I also list other sites such as their professional organizations and Internet communication sites.

As one can deduce, I am a fan of distance education. Students have a distinct advantage in such courses because the instructor is much more available for assistance when the student needs it and not when the instructor happens to be in their office. Students are much more comfortable in their own environments when learning. This facilities comfort and accessibility to information needed to support a course. Drawbacks to using distance education range from the inane to the incomprehensible. Some students may resist the idea to go online for any reason. Others may feel that they are doing too much "work" for a course if you have resources on the Internet and virtual office hours. If you teach a course such as "Educational Methods and Technology" as I do, then it is essential to emphasize these skills. If you are thinking about teaching with distance education, I suggest you check out my web site and utilize some of those resources. It is http://people.morehead-st.edu/fs /l.lennex/index.htm. This page will lead to course syllabi, special projects, such as web pages, and supporting technical information. The web site for the MSU Office of Distance Education is http://www.morehead-st.edu/units/distance/nn4home.html. Both sites offer excellent resources for beginning, then maintaining, distance learning courses.

PREPARING TO TEACH: BUILDING AN EPISTEMOLOGY BASED ON PRACTICE AND THEORY

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Teachers' beliefs about learning and the nature of understanding have been shown to perform a central role in mediating the quality of student learning in the classroom (Maor & Taylor, 1995). Brickhouse (1990) explored this relationship specifically between teachers' understanding of science and their classroom instruction through interviews and observations. She arrived at a similar conclusion to that of Maor and Taylor (1995) noting that teachers' beliefs influence the way their students learn science.

The authors' position is that the preparation of science teachers requires the development of a balance of content and context specific pedagogies (Burry-Stock, 1995; Shulman, 1986) and an understanding of learning and the nature of knowing. Unfortunately, these essential elements are seldom clearly linked in the minds of many new teachers and their epistemologies remain only as an unstated and loose set of beliefs, attitudes, and values regarding knowledge acquisition and teaching for understanding. Regardless of the informality of this epistemology, these beliefs effect personal values which influence evaluative and judgmental functions (Rokeach, 1970; Schwandt, 1997). These values further predispose individuals to specific actions and choices in their teaching thus the link between beliefs/epistemology and instructional strategies/pedagogical choice.

Context and Background

The Rationale Paper

This paper examines a preservice methodology, the writing of a "science teaching rationale paper." The efficacy of this instructional approach will be quantitatively and qualitatively explored, documenting successes and providing details about integration of the science teaching rationale into the methods classroom milieu. The rationale paper encourages preservice teachers' to explore and write about the linkage between their own fundamental epistemology, that is, their beliefs about the nature of knowledge and justification (Maor & Taylor, 1995; Schwandt, 1997), and their anticipated daily science teaching routines.

Methods such as cooperative learning, open-ended inquiry, performance assessment, and the use of questions are thought to be more efficient for increased learning in science than direct instruction (Fosnot, 1996; National Research Council, 1994; Osborne & Wittrock, 1983; Penick, Crowe & Bonnstetter, 1996; Yager, 1995). These teaching approaches are grounded in research on teaching and learning, but are often "presented" as only a series of skills to master. The basis of this study to help students link practice and theory is the student-generated science teaching rationale (STR). The STR is a required research-based paper that each student writes, rewrites, and may be required to defend in a 15 minute interview. The science rationale is an end-of-term assignment in the authors' science methods courses that requires students to meld contemporary research with an actual vision of future practice. The rationale provides a window into how the individual student will eventually teach, what they as the teacher will be doing, and what their students will doing as a result of their actions. The rationale provides the goals for teaching and the theoretical basis for content, pedagogical, and epistemological choices. The essence of the process and the event of writing the rationale is an attempt to provide students with, as (Kagan, 1992) explains, an image of self as the teacher.

Literature indicates that Penick (1986) originated the discussion of the development of a science teaching rationale as a necessary prerequisite for a beginning science teacher to encourage thoughtful consideration and reflection of research-based choices of teaching strategies. The concept of the rationale was further explored by Clough (1992) and again by Veronesi (1998). Penick (1986) argued that beginning teachers who develop a research-based rationale for teaching science are better prepared to self-evaluate, which is a key element of reflection in action (Schön, 1988). This ability augments and encourages the habits of a reflective practitioner. In short, these future teachers have the opportunity to compare the model of teaching science they outlined in their rationale to the teacher they have or will become at any point in time. Penick (1986) and later Varrella (1997) also asserted that teachers who have a goal-centered, research-based rationale for teaching science will more likely stay in tune with science education reform and examine how their beliefs about teaching should be modified to reflect this new knowledge.

Purpose of this Research

The inclusion of a research-based science teaching rationale has gained favor among science teacher educators with time and continued success (Tillotson, 1998; Veronesi, 1998). However, these studies serve as a beginning only and a further study that documents student perceptions about this potentially pivotal preservice activity via a more disciplined approach was needed.

This research also advances notions put forth by Pajares (1992) who argued for a research focus on preservice students' beliefs toward constructs in teaching and learning. Pajares (1992) notes that current definitions for research in beliefs can be defined from a great number of conceptual frameworks that include: attitudes, values, judgements, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principals, perspectives, repertories of understanding, and social strategies. Other workers who have focused on teacher beliefs discussed the role between the nature of teacher beliefs and the impacts these beliefs have on instructional practices in the classroom (Brookhart & Freeman, 1992; Goodman, 1988; Jakubowski & Tobin, 1991; Kagan & Tippins, 1992; Munby, 1982; Wilson, 1990). In addition, if Pintrich's (1990) suggestion that beliefs are going to become the most important aspect of teacher education, then research in this area becomes imperative.

To encourage our students to become thoughtful and reflective teachers who can act on their reflections (Abell & Eichinger, 1998; Schön, 1988) we must provide opportunities to experience the value of discussion, synthesis, and reflection within their preparation programs. The authors have found the science teaching rationale an effective approach to establish a nexus for the study and discussion of theory-based readings and the subsequent applications for the practical purpose of improved teaching efficacy among their preservice students. This experience within the preservice setting addresses the well-documented need to strengthen the relationship between research, beliefs, and actual practice; helping our students "recognize the complexity and diversity of both . . . acknowledging that the relationship between the two is interactive and multifaceted" (Calderhead, 1993, p. 17).

Experiences and evidence shared in this paper show that the development of a personal, research/practice-based rationale is one of the more challenging and rewarding opportunities that preservice teachers experience in their quest to become "The best teacher I can be." (This is the title of a teaching rationale by one of the second author's elementary preservice students.) The challenge stems from the epistemological questions with which the students must begin to grapple in the authors' preservice classrooms and the fundamental challenge of writing a research-based paper (often the students' first). Finding the ultimate answer is not the goal, rather the goal is to begin a life-long professional habit of thoughtful reflection on effective teaching that draws on the best that research and strongly held personal experience can provide. This pivot point in our preservice programs encourages our students to become thoughtfully enmeshed in the, deep debate on matters of teaching and learning (e.g., theoretical, philosophical, experiential, multicultural, religious, feminist, and environmental) (Matthews, 1998).

Setting

The instructors at both sites share intent, constructivist epistemologies, and overall goals for students related to the outcome of the rationale; however, course timelines differed. At site 1, all students were on a quarter system. There was only one science methods course for elementary students, which was ten weeks long. The rationale paper was the last project, due on finals day (during week eleven). At site 2 the science methods course is a semester long and is precluded by a general methods course. Both authors share the same general goals in their methods classrooms. By modeling an inquiry based approach, a balance is established between experience in techniques and curriculum development and exploration of the literature linking theory and practice.

Site 1

Thirty-four preservice students, 20 winter quarter 1997 and 14 spring quarter, 1998, comprised the study population at Site 1. These students were undergraduates, most of who were in their junior year of college, having already been admitted to the teacher preparation program. Due to the compressed timeline (one term – compared to two terms), a "primer" assignment was used to help students focus on expectations and have a preliminary experience in the writing style (research-based) necessary to write a successful rationale. Students wrote a brief research-based paper on a specific subject (e.g., rubrics, Science-Technology-Society, standards, and assessing preconceptions). The assignment was nicknamed the "SOKE" (Synthesis of Key Elements), which tended to be 400-800 words in length, and was based on at least three or four different pieces of science education literature. The expectation was a clear and concise discussion built on current research-based literature with cogent linkages between theory and practice. Students drew from their personal experiences as students and/or pre-student teaching field experiences for the latter element (practice, i.e., day-to-day teaching and learning) and were required to draw from course readings for the former element (theory). This briefer paper provided an opportunity for the instructor to assess students' abilities to write and to provide written comments to each student. The SOKE tended to be very labor intensive for both students and instructor. In the case of the former, many of the students had limited experiences writing a paper melding theory into practice and tended to struggle with this first assignment. The time-intensive detailed responses to their papers by the instructor had the desired effect of setting high, but fair expectations. The provision of rubrics to the students in the course syllabus (see Appendix C) facilitated the final evaluation and grading of the SOKE.

The students drew on a variety of pedagogical strategies in writing their rationale paper. The most common references within the rationales were to questioning and wait-time; STS; learning cycle, pre-, formative, and summative performance assessments; inquiry; democracy in education (an emphasis of the College of Education as a whole); and issues of gender equity. Students drew heavily from course readings to write their rationales. They also tended to draw from germane readings in other courses, particularly in the areas of democracy in education and developmental aspects of younger children, for those elementary majors with a special emphasis in early childhood.

Unlike Site 2, exit interviews were not conducted after students wrote their STR. Students were required to bring an outline to class to share with their colleagues in discussion groups, offering suggestions, references, and constructive criticisms within the discussion. Many of the students also sought out the instructor for advice through office appointments and/or e-mail. Some students brought in full-draft rationales for comments and the instructor would provide brief, formative recommendations. The STR was turned in on finals day as a part of the end-of-term performances. As a measure of the personal importance of the STR, it was noted that students tended to retrieve their rationales quickly to edit and keep as evidence of their teaching philosophy.

Site 2

The intent of the rationale paper used in an elementary science methods course at Site 2 was to help beginning elementary preservice students strengthen their confidence and self efficacy toward science instruction. This pilot study begins discourse on a longitudinal research project in science teacher education to develop an effective strategy to support new elementary teachers' science instruction. The developmental process of reflecting on, and writing a science teaching rationale is a strategy that addresses the concern of lower confidence and sense of self-efficacy.

Forty preservice students were enrolled in a two-semester methods course (first semester general methods, second semester science methods) during the fall semester of 1997. Candidates were assigned to write and orally defend a Research-Based Elementary Science Teaching Rationale (*R-BEST* Rationale, Veronesi, 1998) for teaching science in their future classrooms. Candidates were given the first two months of the semester to write an initial paper for mid-term, get instructor feedback, rewrite and resubmit, then finally orally defend their rationales during a finals week exit interview. The focus of their papers included specifying the research-based methods they would employ in the teaching of science based on their goals for their students' learning. They were then to weave their goals about science learning into a personal vision of their future classrooms.

Each teaching action they envisioned as an alternative was to be based on their goals for students and then linked to relevant research literature. For example, if one of their goals for their students' science learning was to have students communicate their evidence to other group members, they might cite cooperative learning as a research-based means of realizing their goal. Whenever the teacher candidates referred to a teacher action, they were to show evidence of its learning effectiveness in the literature.

Various teaching and learning strategies and constructs for science teaching were modeled for students in their methods course. Each model (e.g. learning cycle, inquiry, open-ended questioning, wait-time) was research-based and the teacher candidates were free to choose those strategies that best fit their goals for their students. Some topics that received a great deal of perusal included constructivism, inquiry, questioning, Science, Technology, and Society (STS), cooperative learning, and alternative and performance assessment.

The final evaluation of their understanding of teaching elementary science was demonstrated through a fifteen-minute oral defense of their rationale during finals week of the second of the two-semester methods sequence. Students were assessed on the completeness of their thoughts and on how well they had incorporated research-based methods into their explanations. As with any assessment, the quality of explanation ranged from very strong and articulate with substance to very week, inarticulate with little knowledge of any research-based literature. The candidates completed the survey used in this research on the last day of class. Most began student teaching during the spring, 1999 semester, and received certification in May of 1999.

Design and Procedure

The study is a mixed quantitative and qualitative design concentrating specifically on elementary preservice students' experiences and opinions on the value of the rationale as a part of their preparations to become science teachers. The instructional methods and strategies and evaluative tools discussed here emerged hermeneutically. Dialog and collaboration between the two co-authors influenced the refinement of these elements including self-reflection on teaching efficacy and previous graduate school experiences (where the rationale paper strategy was first introduced to both researchers).

The population (N = 74) for this study was drawn from three undergraduate level elementary science teacher preparation courses taught at two different universities, one in Appalachia and the other in New England. The sample represents over 90% of the enrollments in these classes (response to the questionnaire was voluntary). A post hoc design was used (Creswell,

1994) and data were collected at the end of the term after the students had completed all course work. It was the researchers' contention that only at this point could students reflect accurately on their experiences and the merits of the rationale paper within their program of study. The primary data gathering instrument was a questionnaire.

The questionnaire (the "Self Reflection Survey for the Science Teaching Rationale" or "STR") used a nominal (Likert) scale with four categories including: SA = Strongly Agree; A = Agree; D = Disagree; and SD = Strongly disagree. Twenty-nine items were included in the questionnaire. Two additional open-ended response items were included inviting comments on factors that assisted the students in writing their rationale (see Appendix A).

Given the data were gathered from two different institutions (n = 36 and n = 34), a one-way analysis of variance was used to compare the responses of the two study subpopulations to the 29 item questionnaire (see Appendix A). One item, #10 was eliminated from the study before analysis, leaving 28 questions. It was found that responses to 23 of the remaining 28 original items in the questionnaire did not differ significantly between the subpopulations at the .05 level; hence the authors chose to complete all further data analysis using a study population of N = 74 (34 at Site 1 and 40 at Site 2). Statistical measures of internal validity and reliability were computed using these data. The results provide insight into the relationships between preservice teaching approaches and student views and performance from two separate, but statistically similar (regarding the majority of the response patterns) settings.

Questionnaire (Instrument) Development

The 11 item instrument reported on by Veronesi (1998) was the predecessor of this 29 item self-reflection survey for the science teaching rationale (STR). The survey for the STR (see Appendix 1) discussed here included 18 positively worded questions, for example:

3. I *truly* believe what I wrote in my STR and will try to implement these ideas in my classroom.

SA A D SD

20. Preparing the STR helped me focus on things that will make me a better teacher.

SA A D SD

Negative wording was used for 11 other questions found in the STR. Examples include:

4. What I wrote in my STR was done only to get a good grade.

SA A D SD

9. My STR does not really represent the realities of the classroom.

SA A D SD

A colleague at site 2, with expertise in psychometrics, responded to and provided formative responses to the authors before finalization of the instrument reported on in this study. Data were collected from the methods students after completion of their rationales. Students signed a release granting the researchers permission to use their responses, but not their names.

Preliminary Data Analysis and Related Discussion

All data were converted to a common scale for convenience of analysis. Specifically, the responses to the positive questions were ranked on a range of 1 - SD (strongly disagree), to 4 – SA (strongly agree). To create a common positive scale for data analysis, the scoring range was reversed for the 11 negatively worded questions. Specifically, a "4" representing a strongly disagree (SD), was converted to "1" representing a strongly agree (SA). Therefore a student who was positive about the "rationale experience" would strongly agree (ranked numerically as a 4) with the positive questions and strongly disagree (also ranked numerically as a 4) with negatively worded questions. The result is a set of means that reflect the students' views on the value of their personal STR with "4" indicating a strongly positive view and "1" indicating a strongly negative opinion on each of the 28 items (note question #10 was dropped) included in the final analysis.

A series of means were calculated for site 1 and site 2 separately and are summarized in Table 1. All data were analyzed using SPSS for the microcomputer (Noru_is/SPSS Inc., 1997). On visual inspection, alone it is notable that although the timeframes were very different — 1 quarter (Site 1) compared to 2 semesters (site 2) — the patterns of responses are remarkably consistent. However, before collapsing the data into one set to explore fundamental psychometric properties of reliability and validity of the instrument, the two subsets were compared using a one-way ANOVA.

The One-Way ANOVA, an indicator of similarities and differences between the two means on each response variable, given the samples were independent and included different subjects (Peers, 1996). Table 1 summarizes the results of the One-Way ANOVA and includes the F-statistic and the probability (p-value).

Item 10 of the STR had been previously eliminated by the researchers as a question that had generated confusion on the part of the students (from their written comments and responses). On inspection, the response patterns for the two subsets of students held to the same pattern. However, the means and standard deviations were different enough on items 2, 5, 11, 26, and 29 to generate a significant difference at the $p \leq 0.01$ level. The authors attribute the significant difference in the response patterns to items 2, 5, and 11 to difference in teaching style and expectations of preservice teachers between site 1 and site 2. Specifically for item 2, there were site-based differences in the types of intermediate activities leading up to the writing of the final rationale; for item 5 there was no interview at Site 1 and so the question was hypothetical at best for site 1 students. For item 11, only a portion of the students at Site 1 were actively developing portfolios.

Table 1

Summary of Descriptive Statistics and Results of One-Way ANOVA for Site 1 (*n* = 34) and Site 2 (*n* = 40).

	Descriptive Statistics					One-way ANOVA	
Question #	N	Minimum	Maximum	M	SD	F	p
Item 1	34	3	4	3.441	0.504	0.565	0.45
Item 1	40	2	4	3.350	0.533		
Item 2	34	1	4	2.794	0.770	17.264	0.00
Item 2	40	1	4	3.475	0.640		
Item 3	34	3	4	3.824	0.387	0.000	0.99
Item 3	40	3	4	3.825	0.385		
Item 4	34	3	4	3.529	0.507	0.056	0.81
Item 4	40	2	4	3.500	0.555		
Item 5	34	2	4	3.471	0.563	4.642	0.03
Item 5	40	2	4	3.200	0.516		
Item 6	34	3	4	3.794	0.410	0.388	0.54
Item 6	40	3	4	3.850	0.362		
Item 7	34	3	4	3.706	0.462	0.228	0.63
Item 7	40	2	4	3.650	0.533		
Item 8	34	2	4	3.676	0.535	2.740	0.10
Item 8	40	3	4	3.850	0.362		
Item 9	34	3	4	3.471	0.507	1.975	0.16
Item 9	40	2	4	3.650	0.580		
Item 11	34	3	4	3.382	0.493	9.707	0.00
Item 11	40	3	4	3.725	0.452		
Item 12	34	3	4	3.588	0.500	2.682	0.11
Item 12	40	2	4	3.775	0.480		
Item 13	34	3	4	3.529	0.507	1.626	0.21
Item 13	40	3	4	3.675	0.474		
Item 14	34	2	4	3.441	0.561	0.468	0.50
Item 14	40	2	4	3.350	0.580		
Item 15	34	2	4	3.471	0.615	0.023	0.88
Item 15	40	2	4	3.450	0.552		
Item 16	34	3	4	3.676	0.475	1.275	0.26
Item 16	40	2	4	3.800	0.464		
Item 17	34	2	4	3.147	0.657	0.021	0.89
Item 17	40	2	4	3.125	0.648		
Item 18	34	2	4	3.118	0.686	0.014	0.91
Item 18	40	2	4	3.100	0.591		

Item 19	34	1	4	3.235	0.741	0.369	0.55
Item 19	40	2	4	3.325	0.526		
Item 20	34	3	4	3.676	0.475	1.459	0.23
Item 20	40	3	4	3.800	0.405		
Item 21	34	2	4	3.088	0.621	0.066	0.80
Item 21	40	2	4	3.125	0.607		
Item 22	34	2	4	3.471	0.615	0.595	0.44
Item 22	40	2	4	3.575	0.549		
Item 23	34	2	4	3.353	0.646	2.171	0.14
Item 23	40	3	4	3.550	0.504		
Item 24	34	2	4	3.118	0.591	0.488	0.49
Item 24	40	1	4	3.000	0.816		
Item 25	34	2	4	3.412	0.557	1.762	0.19
Item 25	40	3	4	3.575	0.501		
Item 26	34	1	4	2.853	0.702	4.654	0.03
Item 26	40	1	4	2.450	0.876		
Item 27	34	2	4	3.412	0.557	1.762	0.19
Item 27	40	3	4	3.575	0.501		
Item 28	34	3	4	3.529	0.507	1.095	0.30
Item 28	40	3	4	3.650	0.483		
Item 29	34	3	4	3.382	0.493	9.707	0.00
Item 29	40	3	4	3.725	0.452		

Note: Item sets with significant differences (i.e., $p \leq 0.01$ level) are noted in the grayed area.
Item 10 was eliminated before data analysis.

The response patterns for question 26 had a broader range than any other item (note the higher standard deviations for sites 1 and 2) indicating ambivalence regarding the importance of further field experience (item 26). Question 29 (relates to "what [their] students would be doing as reflected by their rationales") poses a more interesting contrast. The students at Site 1 (n = 34) were more concerned about what they would be doing, when compared to the students at Site 2 (n = 40). A concern about procedural and management issues is most common among novices (Berliner, 1986, 1988). Since most of the students at Site 1 were undergraduates and, in general, were less experienced and younger than the population at Site 2, this significant discrepancy is not surprising.

The full data set (N = 74) can be found in Table 2. Recalling the reversal of the numeric ranking of the negative questions, it can be surmised that students were very positive about their STR. The means are all well above three. The range indicates that in all instances there were some students who were less positive (i.e., note the range of responses — 2 = disagree to 4 strongly agree) on specific questions, but in general the means indicate a very positive view of the STR writing experience. In addition, the standard deviations are relatively small, indicating a close dispersion around the means, which are positive (i.e., agree to strongly agree).

Although only 23 of the items were shown to have no significant differences that the five percent level, it was decided to keep 28 items (excluding #10) for the remaining analysis. This choice was based on the preliminary nature of this study, the relatively small N (74) and the consistent patters of positive student responses on their rationale experience. In addition, further exploratory analysis indicated little overall effect or loss of power when reducing the analysis to only the 23 items with no significant differences between the two subpopulations. For example: A five factor analysis for the 23 items yielded a solution accounting for 64% of the variability and a five factor solution for the 28 items yielded a solution accounting for 61% of the variability; and in both instances the overall alpha reliability coefficient remained above .90.

Factor Analysis, Reliability, and Construct Validity of the STR

To establish a level of reliability, item-to-total correlations were examined (Table 2, last column) and a Cronbach's alpha reliability coefficient, an indicator of internal consistency, was calculated. The value of · = .92 is large, indicating that the instrument is highly reliable. With the exception of item 24 ($r = .15$), item-to-total correlations were acceptable. Twenty-one of the 28 items showed a moderate to high level of correlation ($r \geq .5$).

Table 2

Summary of Descriptive Statistics for the Full Data Set and Reliability Analysis (N = 74).

		Descriptive Statistics				
Item #	**N**	**Minimum**	**Maximum**	**M**	**SD**	**Item-to-Total Correlation**
Item 1	74	2	4	3.39	0.52	.46
Item 2	74	1	4	3.16	0.78	.29
Item 3	74	3	4	3.82	0.38	.57
Item 4	74	2	4	3.51	0.53	.55
Item 5	74	2	4	3.32	0.55	.31
Item 6	74	3	4	3.82	0.38	.48
Item 7	74	2	4	3.68	0.50	.60
Item 8	74	2	4	3.77	0.46	.62
Item 9	74	2	4	3.57	0.55	.66
Item 11	74	3	4	3.57	0.50	.54
Item 12	74	2	4	3.69	0.50	.56
Item 13	74	3	4	3.61	0.49	.63
Item 14	74	2	4	3.39	0.57	.44
Item 15	74	2	4	3.46	0.58	.64
Item 16	74	2	4	3.74	0.47	.69
Item 17	74	2	4	3.14	0.65	.55
Item 18	74	2	4	3.11	0.63	.55
Item 19	74	1	4	3.28	0.63	.53
Item 20	74	3	4	3.74	0.44	.70
Item 21	74	2	4	3.11	0.61	.57
Item 22	74	2	4	3.53	0.58	.59
Item 23	74	2	4	3.46	0.58	.62
Item 24	74	1	4	3.05	0.72	.15
Item 25	74	2	4	3.50	0.53	.70
Item 26	74	1	4	2.64	0.82	.33
Item 27	74	2	4	3.50	0.53	.55
Item 28	74	3	4	3.60	0.49	.66
Item 29	74	3	4	3.57	0.50	.59

For the questionnaire · = .92.

Factor Analysis, Reliability, and Construct Validity of the STR

To establish a level of reliability, item-to-total correlations were examined (Table 2, last column) and a Cronbach's alpha reliability coefficient, an indicator of internal consistency, was calculated. The value of · = .92 is large, indicating that the instrument is highly reliable. With the exception of item 24 ($r = .15$), item-to-total correlations were acceptable. Twenty-one of the 28 items showed a moderate to high level of correlation ($r \geq .5$).

A five component factor analysis was generated accounting for approximately 61% of the variance (see Table 3). Although a rotation with up to eight factors, all with eigenvalues greater than 1 (which indicates "stability" of the factors (Girden, 1996) could have been used, it was felt that this would create an excessive and confusing set of categories. Guilford's rule of thumb suggests two subjects for every one item (Burry-Stock, 1996) for initial exploratory factor analyses such as this one. That minimum is satisfied for our exploratory purposes with an N = 74 and 28 different items in the questionnaire. Descriptive phrases for the categories representing the rotated factor loadings from the data gathered using the original questionnaire (Appendix 1) were created. The five categories include:

- Category I consists of eight measures, "connecting [the students'] ideas with the realities of teaching."
- Category II describes eight measures defining the, "personal significance of the science teaching rationale" to the individual methods students who responded to the questionnaire.
- Category III explores six measures of the students', "confidence in and construction of the science teaching rationale."
- Category IV consists of three measures relating the, "importance of the elements and beliefs outlined in the science teaching rationale" to the students' overall epistemology.
- Category V provides insight through three measures related to the students' views on the value of and, "effective use of time related to the development of the[ir] science teaching rationale."

To facilitate use by other methods instructors, the instrument was revised and renumbered to reflect the outcome of the factor analysis (see Appendix 2).

The loadings on the factors are modest to high (.43 - .87). The one exception is item 5, which had a relatively low loading and final communality estimate (.39) indicating a lesser overall relationship to the five factor solution. The communalities, representing the proportion of the variance of that can be explained by the items (factors) are also modest to high with 21 of the 28 items having a final communality estimate of greater than or equal to .50. The measures which are least associated with the five factors included writing the STR for a good grade (item 4), confidence to answer questions about the STR (item 5), and the value and relation of various field experiences to the writing of the STR (item 19). Six measures were highly associated (a communality of .70 - .85) with the five factors and included items 3, 7, 12, 16, 23, and 25. Collectively they are related to the method students' beliefs in and confidence about their rationale papers as an honest representation of their teaching.

A case for overall construct validity and general reliability, within this study, can be made. Contributing to this position is the stable factor structure and communalities, the Cronbach's alpha (reliability) of .92 for the instrument, and the amount of variance accounted for in the factor analysis (61%). The item-to-total correlations (.44 - .70, for 25 of the 28 items) and the face validity of the items related to the subject of the study also lend support for general construct validity.

Student Comments and Opinions

The students from both populations were positive in their perceptions and beliefs toward the final drafts of their rationales. Each candidate was given the opportunity to comment on any item and specifically encouraged to comment at the end of the questionnaire. The candidates at site 1 discussed three main areas of value in their rationales. First, candidates felt that they were confident about what they had written and therefore were excited about using their rationales during a job interview: "I know [it] will be a strong reference in my future job interviewing." Second, candidates were appreciative that the process of writing their rationales forced them to "dig" into

Table 3.

Factor analysis — Principle Component Solution with Varimax Factor Rotation for the Science Teaching Rationale (STR), N = 74.

STR Item	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	Final Communality Estimates
12	.87					.80
16	.85					.85
9	.68	.36				.63
7	.65			.60		.78
29	.59			.36		.61
25	.58	.51				.72
8	.57					.54
20	.45			.40		.61
13		.67				.61
15		.67			.37	.67
22		.67				.60
14		.63		.39		.62
21		.63				.52
23	.39	.62				.70
28	.37	.53				.57
4		.43		.36		.40
2			.69			.61
1			.59			.45
11			.54			.50
18		.42	.49			.60
27	.45		.46			.49
19			.45			.41
3				.73		.73
6				.65		.56
5				.30		.39
24					.76	.60
26					.61	.45
17			.42		.50	.57
Variance explained by each factor	4.73	4.40	2.96	2.42	2.11	16.62
% variance explained by each factor	17%	16%	11%	9%	8%	61%

the state and national science standards in a practical way. Third, students felt that they had a much clearer vision of their future science teaching practices because of the reflective thought they used in writing their rationales. Many students independently stated that they were going to use the ideas they expressed in their rationales in a practical way. A representative response was, “I think the rationale paper is the clearest and most helpful single assignment I have had in this program!” Candidates at Site 1 responded in similar ways. For example, these students similarly focused on how the rationale made them “think” about teaching elementary science. A few candidates at Site 1 also felt their “beliefs about teaching elementary science were finally realized.”

Candidates at both sites also discussed the sources for the information they used in their rationales. Not surprisingly, the methods course itself was frequently referenced. Decisions of the instructor in terms of curriculum and guidance did have an impact on their perceptions and written rationale. It is also interesting to note that communicating with their peers ranked high in the development of their teaching rationales.

Following is a list of sources that are ranked highest to lowest from each Site. The frequency of responses dictated the order of these reference sources and they are summarized in Table 4.

These data are interpreted to mean that both instructors had a primary impact on these methods students. The instructor at Site 2 indicated that, “ERIC and the national/state standards were places to find out about research-based teaching strategies that would address their goals”. What is not as clearly indicated by this data are the specific instructor characteristics that may have been contributory to the prominence within the relative ranking of the preservice students’ perceptions. It is the belief of the instructors that modeling desired teaching habits (e.g., wait time and varied assessments of students’ work) surely played an important role as well since modeling was a clear, shared goal of both instructors. Other habits included: instructor enthusiasm, modeling of research-based pedagogy, engaging activities, constant support of students’ ability and attitude

Table 4

Ranking of Sources for the STR from Site 1 and Site 2 Methods Students.

Site 1	Site 2
Primary Importance:	Primary Importance:
1. Field experiences	1. The instructor (much individual feedback given)
2. Handouts in class	2. Library research-specific journals named
3. Class texts	3. Peers
4. The instructor	4. Internet
1. Secondary Importance:	1. Secondary Importance
2. Instructors from other classes	2. Experiences from previous jobs
3. Peers	3. State and National science standards
4. Library	4. Cooperating practicum teacher
5. Science Standards	5. Instructors from other classes
	6. "Remembering what my experiences were like in elementary science"

toward science and teaching, and ungraded critique of a first draft. (These comments were consistently evident in end-of-term student evaluations of the site 1 and site 2 instructors as well.) Candidates from Site 1 noted especially the specific contributions of the instructor in terms of insight and classroom experiences. The role of the instructor also had an impact on the final rationale at Site 1 when the handouts and the course texts are considered to be instructor-chosen (part of course requirements).

It is clear by the student comments at both sites, that these methods students had an overall positive view about their final science teaching rationales. They noted that they were proud of their work. The students indicated they would be willing to share it with their cooperating teachers during student teaching and that they planned to use their rationale as further evidence of their understanding of teaching and learning when interviewing for jobs. Students noted that the rationale "helped [them] pull ideas together in [their] own head" and that "it makes you think about how you want to teach."

Discussion and Implications

This study extends earlier work (Veronesi, 1998) on the rationale paper as an effective strategy to help extend the depth and breadth of preservice students personal, research/practically-based rationale for teaching elementary science. The students' rationales were based on two elements: 1) their personal studies of pedagogy and 2) the nature of knowledge building in the learning environment (epistemology) as they interpreted it at the end of their methods courses. This study establishes baseline data that can be further explored through classroom-based observation and additional self-reflection as these same methods students are followed into their first few years of teaching. Pajares (1992) argued extensively for research into teacher beliefs because, he asserts, they ultimately influence what a teacher does in the classroom. He discussed the need to address beliefs in a context that is defined in terms of connections to sub-constructs and other affective structures.

Individuals from Sites 1 and 2 had positive perceptions about teaching elementary science after their rationales were written. They perceived that the process of writing and defending (Site 2 only) the rationale paper focused their attention on how to teach science to children using research-based strategies and toward better teaching practices in general. The students communicated this positive perception through their responses to the 28 items in the STR self-report survey and through supporting written comments.

Students noted that they were proud of their work. The indicated they would be willing to share their rationales with their anchor teachers during student teaching, and planned to use their rationale as evidence of their understanding of teaching and learning when interviewing for future teaching jobs. Students described the rationale as an assignment that "helped me pull ideas together in my own head" and that "it makes you think about how you want to teach [based on what we know]."

The STR instrument, as used in this study, has been shown reliable and valid as used in this study. However, other users are cautioned that reliability and validity would need to be reestablished in another setting, generalizability cannot be established at this point. Other factors are critical for student success as well. It is the belief of the authors that a focus on a mix of technique, literature, and philosophical development is necessary to provide the appropriate background and experience. The authors emphasized modeling of desired skills and attitudes during their teaching, provided clear expectations (e.g., the rubrics attached), and provided examples of previous students' STRs for the classes in this study.

Conclusions

An indication of the value of the STR to the students is evident through the consistently high means for each item on the questionnaire. Evidence from this study indicates that the rationale is a cornerstone activity in the pedagogical and philosophical development of future teachers who made their learning environment choices purposefully at both sites. Students' pride in their work and confidence in the value of their STR are noteworthy and offer insight into the formation and enduring beliefs and complimentary practices of these future teachers.

The development of a science teaching rationale is a challenging and rewarding opportunity for the preservice teachers in their preparations to become the best teacher possible. Finding the ultimate answer is not the goal of the rationale. Rather the goal is to initiate among the students the life-long professional habit of thoughtful reflection on effective teaching, drawing on the best that research and personal experience can provide. This key element in the authors' preservice programs encourages their students to become thoughtfully enmeshed in the deep debate on theoretical, philosophical, and pedagogical matters (Matthews, 1998) that will influence their beliefs about learning and corresponding teaching practices.

The process of surveying the students' beliefs and perceptions toward teaching science after their rationales is only one piece of the puzzle. No one would argue that many variables influenced the respondents documented positive views toward the rationale paper experience. However, the positive trend details evidence that these individuals had, in the least, entered student teaching with a more positive attitude toward science and science teaching and a greater confidence in their choices of appropriate pedagogical strategies. Longitudinal studies of these students that explore related and confounding factors are warranted at this point in further exploration of the rationale as a tool in preservice teacher development.

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APPENDIX A

Self-Reflection Survey for the Science Teaching Rationale (STR)

(Original used for study purposes)

1. The process I went through in writing my Science Teaching Rationale (STR) made me feel more confident about teaching science.
   SA A D SD

2. The rough draft/outline of my STR, which was critiqued with suggestions for improvements, helped me to understand how to construct my STR.
   SA A D SD

3. I *truly* believe what I wrote in my STR and will try to implement these ideas in my classroom.
   SA A D SD

4. What I wrote in my STR was done only to get a good grade.
   SA A D SD

5. I am confident that I can respond to any question regarding what I wrote in my STR during a 15 minute exit interview.
   SA A D SD

6. Topics that were suggested (like wait-time, constructivism, questioning, and hands on science) to write about will be important to me for teaching science to children.
   SA A D SD

7. Topics that I have written about in my STR do not relate to other subject matter areas or aspects of school teaching.
   SA A D SD

8. I probably will not use the ideas in my STR to teach science in the elementary school.
   SA A D SD

9. My STR does not really represent the realities of the science classroom.
   SA A D SD

10. I would prefer to choose my own topics to write about in my STR.
    SA A D SD

11. The STR will be an important element of my portfolio.
    SA A D SD

12. I see no relationship between my STR and the course content of my science methods course(s).
    SA A D SD

13. Now that it is finished, I am glad I wrote my STR.
    SA A D SD

14. I have used ideas and materials from other education courses to help me write my STR.
    SA A D SD

15. I am proud of the work I did as represented through my STR.
    SA A D SD

16. I see no relationship between what my elementary students will be doing in my future science classes and what I wrote about in the STR.

SA **A** **D** **SD**

17. Informal discussions with my classmates (in or out of class) helped me to write my STR.

SA **A** **D** **SD**

18. Informal discussions with the instructor helped me to write my STR.

SA **A** **D** **SD**

19. I used my field experiences (in this and/or other classes) to help me write and explain points in my STR.

SA **A** **D** **SD**

20. Preparing the STR helped me focus on things that will make me a better teacher.

SA **A** **D** **SD**

21. I will share my STR with the classroom teachers I work with when I student teach.

SA **A** **D** **SD**

22. I will not look at my STR again.

SA **A** **D** **SD**

23. My time could have been better spent working on curriculum and other types of projects.

SA **A** **D** **SD**

24. Working collaboratively and generating a "group STR" would have been a more beneficial way for me to complete this project.

SA **A** **D** **SD**

25. The part of STR that describes what I will be doing in my class is an important part of my overall rationale for teaching.

SA **A** **D** **SD**

26. My time could have been better spent with more field experiences.

SA **A** **D** **SD**

27. Writing the STR has helped me construct the "big picture" of how I will teach science.

SA **A** **D** **SD**

28. Writing the STR should be dropped from the course expectations.

SA **A** **D** **SD**

29. The part of my STR that describes what my students will be doing in my class is an important part of my overall rationale for teaching.

SA **A** **D** **SD**

List things (people, resources, experiences, etc.) which helped you write your rationale.

Other comments.

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APPENDIX B

Self-Reflection Survey for the Science Teaching Rationale (STR)

(Rearranged to reflect the factor analysis and one question, #10 from the previous iteration, has been dropped — may be used with permission of either author)

Category 1: Connecting ideas with the realities of teaching

1. I see no relationship between my STR and the course content of my science methods course(s).
SA A D SD

2. I see no relationship between what my elementary students will be doing in my future science classes and what I wrote about in the STR.
SA A D SD

3. My STR does not really represent the realities of the science classroom.
SA A D SD

4. Topics that I have written about in my STR do not relate to other subject matter areas or aspects of school teaching.
SA A D SD

5. The part of my STR that describes what my students will be doing in my class is an important part of my overall rationale for teaching.
SA A D SD

6. The part of STR that describes what I will be doing in my class is an important part of my overall rationale for teaching.
SA A D SD

7. I probably will not use the ideas in my STR to teach science.
SA A D SD

8. Preparing the STR helped me focus on things that will make me a better teacher.
SA A D SD

Category II: Personal significance of the science teaching rationale.

9. Now that it is finished, I am glad I wrote my STR.
SA A D SD

10. I am proud of the work I did as represented through my STR.
SA A D SD

11. I will not look at my STR paper again.
SA A D SD

12. I have used ideas and materials from other education courses to help me write my STR.
SA A D SD

13. I will share my STR with the classroom teachers I work with when I student teach.
SA A D SD

14. My time could have been better spent working on curriculum and other types of projects.
SA A D SD

15. Writing the STR should be dropped from the course expectations.
SA A D SD

16. What I wrote in my STR was done only to get a good grade.
SA A D SD

Category III: Confidence in and construction of the science teaching rationale.

17. The rough draft/outline of my STR, which was critiqued with suggestions for improvements, helped me to understand how to construct my STR.
SA A D SD

18. The process I went through in writing my Science Teaching Rationale (STR) made me feel more confident about teaching science.
SA A D SD

19. The STR will be an important element of my portfolio.
SA A D SD

20. Informal discussions with the instructor helped me to write my STR.
SA A D SD

21. Writing the STR has helped me construct the “big picture” of how I will teach science.
SA A D SD

22. I used my field experiences (in this and/or other classes) to help me write and explain points in my STR.
SA A D SD

Category IV: Importance of the elements and beliefs outlined in the science teaching rationale.

23. I *truly* believe what I wrote in my STR and will try to implement these ideas in my classroom.
SA A D SD

24. Topics that were suggested (like wait-time, constructivism, questioning, and hands on science) to write about will be important to me for teaching science to children.
SA A D SD

25. I am confident that I can respond to any question regarding what I wrote in my STR during a 15 minute exit interview.
SA A D SD

Category V: Effective use of time related to the development of the science teaching rationale.

26. Working collaboratively and generating a “group STR” would have been a more beneficial way for me to complete this project.
SA A D SD

27. My time could have been better spent with more field experiences.
SA A D SD

28. Informal discussions with my classmates (in or out of class) helped me to write my STR.
SA A D SD

Developed by Pete Veronesi, SUNY-Brockport, and Gary Varrella, George Mason University. ©authors 2000. Special thanks to Catherine Glascock, Ohio University, for assistance and review.

APPENDIX C

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Synthesis of Key Elements & Rubric
(SOKE)

The SOKE will help you begin to think about your readings in terms of your rationale for teaching. It is also a method to allow you to practice making connections between your thinking, various readings and the practical world of learning and teaching. It is a form of active reflection (Schön, 1983), which is a part of your developmental path as a future teacher. By having you share your works with your colleagues in a collaborative discussion, I hope to encourage the creation of a learning community within our classroom (Senge, 1990). Change in teachers is accomplished overtime and is a nonlinear process. The results in such instances tend to be more enduring and should foster the development of a set of beliefs and attitudes about teaching and learning (Fullan & Miles, 1992; National Research Council, 1996; Pajares, 1992). The SOKEs also provide a preliminary feedback loop for the instructor to help you extend your thinking and refine your writing. Remember, state it clearly, back up your points with substance, and be done with it. Four hundred words seems about optimum, but please don't count the words, rather, make you points.

You'll note above that I have also provided a model of how you should insert text citations. I am not going to be fussy about it, but try to imitate this style please. (It is called "APA" for the American Psychological Association). Keep in mind the synthesis should meld your readings, your experiences as a teacher and as a student, and pertinent theory (drawn from class readings as well as from elsewhere). Don't force your writing; rather connect it together with flow of thought and defensible discussion/argument patterns.

Note, always start out by noting the article that was your focus. Others cited will be included with the references. You must write your own paper, but don't hesitate to discuss your ideas with and/or edit your colleagues' work prior to completing the assignment. (You can always come see the teacher too!)

References

Fullan, M. G., & Miles, M. B. (1992). Getting reform right: What works and what doesn't. *Phi Delta Kappan*, 73, 744-752.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. Review of Educational Research, 62, 307-332.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.

Senge, P. M. (1990). The fifth discipline. New York, NY: Doubleday.

On the back you'll find a set of guidelines that I'll use to grade your papers

SOKE Rubric

On a 100% scale	**Synthesis (~70%)**	**Construction (~20%)**	**Citations (~10%)**
Outstanding (A)	Connects theory, practice, and readings (more than one) in cogent and well-supported arguments and/or discussion.	Writing is clear, it's obvious that the work was edited, and there is a flow/coherence to the discussion.	3-4 citations
Well Done (A-)	Clearly connects theory, and readings (more than two) practice, and readings in the discussion.	Writing is clear and there is a flow to the discussion.	2-3 citations
Done (B to B+)	Connects theory and reading to synthesize a discussion on the subject of the article. (Notice there are no practical connections).	You got the point across well — without any literary barbarisms.	1-2 citations
Needs improvement (less than a B . . .)	Outlines article discussing the key points discussed by the author	Say what?	Cite what?

*It is difficult to separate synthesis and construction since you have to communicate in writing. Hence communication has to be the overarching focus. I will give a total score only, but this rubric will be my general guide.

**If you're wondering what readings to connect together in your synthesis, the others for the week might be a good start. However, if there are other readings from our class or even one or more from another class that strengthens your position, then use them!

***May be used without written permission.**

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THE SCIENCE TEACHING RATIONALE

Your rationale is a personal statement of who you are/will be as a teacher. The picture must include *you* and your *students*. What will you be doing in and outside of your classroom as a teacher? If I visit you in three years in your classroom, what will I see your students doing, hear them saying, etc.? What will you be doing, saying, etc.? Your discussion should be rich in examples from the literature and from your own experience that demonstrate you have solid reasons, both practical and theoretical for teaching as you do. Evidence of melding the thinking and writings of more than one author is important *(collectively and conveniently called "theory," in the rubric).* Things you might want to consider including: how you will use standards, lesson design to reflect your epistemology (i.e., your philosophy on learning), questioning & wait time I and II, equity, democracy, "authentic" and STS approaches (i.e., relevancy), problem solving, the role of textbooks, safety, assessment and evaluation, learning cycle, lecture (it too has a place, but how, when, for what reason), etc. You must explain how your classroom will operate and what guides and informs your curricular and pedagogical choices!

There will be multiple rationale papers available for review in the methods classroom. **Note:** You may wish to cite our texts in different contexts, from different chapters. This is appropriate, since our texts are rich in theory, models, and practical examples. However, to earn a high mark on your rationale, you must reach to the other readings in the class, and if it suits your rationale — to materials from other classes. You will have already done the reading necessary to write this paper (if you have kept up in class) before it is due. You must build on the ideas, readings and discussions we have to construct your own, coherent and rich science teaching rationale.

Write this paper with the conviction that it will be an important part of the evidence of the kind of teacher you are to become. Think of it as something you would be proud to leave at a school after you have interviewed with them for a job you really, really, want!

On the back you'll find a set of guidelines that I'll use to grade your papers

On a 100%	**Synthesis (~70%)**	**Construction (~20%)**	**Citations (~10%)**
Outstanding (A) **(≥ 94%)**	Connects theory and practice with cogent and well-supported arguments/discussion. The picture of the interactions between students and teachers is clear, rich, and carefully explained and supported through research and examples.	Writing is clear, it's obvious that the work was edited, and there is a flow/coherence to the discussion.	10 citations from different sources including at least 8 from the 608 class. (Also, don't cite 5 chapters each from two different books and expect much credit). Note: I have never seen a top-notch rationale with less than a dozen or so references.
Very Well Done (A-) **(≥ 90%)**	Connects theory and practice with cogent and well-supported arguments/discussion. A picture of the interactions between students and teachers is apparent and is supported by the selected literature.	Writing is clear and there is a flow to the discussion.	8 citations
Well Done (B to B+) **(for a B, ≥ 83%)**	There is ample evidence that the author has considered and included both theory, practice and experience in building their rationale of teaching. Theory is used a foundation for practice	You got the point across well — without any literary barbarisms.	6 citations
Needs improvement (less than a B → ☹)	I hope you won't find yourself needing to worry about this or lesser grades.		